WORLDS IN SPACE

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by Martin Caidin

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FOR GRACE

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This is how we stand

At 3.19 p.m., Mountain Standard Time, on February 24, 1949, the empty shell of a giant V-2 rocket which had blasted free of the earth five minutes before smashed into the New Mexico desert. A little more than six minutes after the V-2 shattered into wreckage, the shell of a second and smaller rocket plunged into the broiling sands of New Mexico.

That second missile, a 16-foot steel sliver known as the WAC-Corporal, had rocketed upwards at 5,100 miles per hour and set man's highest mark in the heavens at 1,300,000 feet above the earth.

Nearly five years have passed since the two-stage combination of the 45-foot V-2 and the smaller WAC-Corporal thundered into the sky. In that time no known rocket flight has surpassed the height of 252 miles and the speed of 5,100 miles per hour attained that day.

The fact that another rocket has not appeared to eclipse the performance of the V-2 and its progeny does not mean that rocket progress has come to a standstill. It is quite probable that, behind the Iron Curtain, Soviet technicians with improved V-2 rockets and superior missiles of their own design have launched giant rockets to greater distances above the earth and at much greater velocities. While we cannot say with certainty that this has occurred, we do know that the Russians are deeply engaged in this field. Their activity is emphasized by the complete lack of publicity that attends

their efforts. It is possible, of course, that the United States has smashed its own five-year-old rocket performance record, but for security reasons prefers the information not to be released at this time.

Although the United States has not publicly launched any other record-breaking missiles since the epochal date in 1949, the design and development of rockets have continued at an accelerated pace. There is much more to increasing our knowledge of rocket design and performance than merely shooting off record-breaking missiles. Dependability, accuracy, efficiency, and many other design ingredients do more to determine successful rocket performance than do a few sensational launchings.

American rocket development policy has progressed along these lines since the programme was initiated in January of 1944. The record-breaking V-2/WAC-Corporal two-stage rocket was only one step towards acquiring increased knowledge of rocket launchings and operations. Actually, the decision to construct and fire the two-stage missile was made in 1946, three years prior to the firing date. Similar launchings have been made since the shot on February 24, 1949, under the programme phase known as Project Bumper, but these were not undertaken for the express purpose of setting new records. They enabled technicians and engineers to gain vital knowledge in handling the treacherous multistage missiles, and to establish in fact the performance of the multistage rocket which heretofore had been only theory.

The more prosaic aspects of tactical and strategic guided missiles cannot be separated from those necessary in space travel. Fuels, motors, performance, temperature ranges, and electronics, all vital necessities in the make-up of any missile, are forerunners of the more advanced equipment which will be embodied in a space ship.

The more experiments with the military missiles and rockets, the less need to grope in the dark for the information indispensable to making space travel a reality.

Prior to the year 1948 space travel was still a matter of interest only to professionals and enthusiastic amateurs. We have no specific date to mark the occasion when the attention of the general public focused on space travel, but December, 1948, may be accepted as an arbitrary turning point.

In that month the possibility that space satellites might some day girdle the earth was discussed in almost every newspaper in the U.S.A. and carried to the public on radio, television, and in hundreds of publications. It was at this time that the Department of Defense lifted the veil of secrecy which had covered certain military projects. It was revealed that the United States Air Force was conducting a fantastic new series of projects, among which was the establishment of giant manned stations in space! Since the prestige of the Department of Defense supported these statements, they were accepted without the ridicule which might have greeted such grandiose proposals had they emanated from a less distinguished source. Unfortunately, the Department of Defense said only that the establishment of such space satellites was a project which was still in its earliest stages; the situation remained somewhat nebulous.

On October 13, 1951, there occurred in New York City an event which indicated that the public had begun to assume that space satellites and flights from the earth to the moon were a realizable reality limited only by the time factor. This was the First Annual Symposium on Space Travel, conducted by and on the premises of the Hayden Planetarium.

This unprecedented symposium left its mark in many ways, not the least of which was the immediate and widespread publicity

which it achieved and merited. The symposium's outstanding characteristic was the fact that the speakers represented not merely space-travel enthusiasts, but leading exponents of the educational, scientific, and political worlds.

When such individuals take upon themselves the responsibility for stating publicly their views on space travel, leaving no doubt that in their collective opinion the realization of space travel awaits only the necessary time and funds, a swing of public opinion from doubt to belief is inevitable. The inevitable occurred.

The programme of speakers at the first symposium reads like an excerpt from a scientific *Who's Who*. These were the participants:

Dr. Albert E. Parr,
Director of the American Museum of Natural History.

Robert R. Coles,
Chairman of the Hayden Planetarium.

Willy Ley,
outstanding authority on rockets.

Robert P. Haviland,
Research Engineer on General Electric's "Project Hermes."

Dr. Fred L. Whipple,
Chairman of the Department of Astronomy at Harvard University.

Heinz Haber, M.D.,
of the Department of Space Medicine, United States Air Force.

Oscar Schachter,
Acting Assistant Secretary-General of the United Nations' Legal Department.

The success of the first Planetarium space-travel symposium assured an annual repetition of the event. On October 13, 1952, the

Hayden Planetarium presented to the public its Second Annual Symposium on Space Travel. Carried over as speakers from the previous symposium were Robert R. Coles, Willy Ley, and Dr. Fred L. Whipple. Distinguished additions included:

George O. Smith,
Radio Research Engineer of the Emerson Radio and Phonograph Corporation.

Dr. Fritz Haber,
Department of Space Medicine of the United States Air Force.

Milton W. Rosen,
Director of the Viking Rocket Project, United States Naval Research Laboratory.

Wernher von Braun,
Technical Director of the United States Army Guided Missile Development Group.

Before we can make an accurate appraisal of the American rocket development programme, nearly all of which is a postwar development, we must understand the tremendous influence German rocket activity exerted on American experiments.

Germany, of course, reigned supreme in rocket development immediately prior to and during World War II. At the peak of rocket activity in Germany (this refers only to major rocket missiles such as the V-2, not the smaller tactical missiles) more than 12,000 persons, including 1,500 scientists and technicians and 8,000 special workers, were engaged in the V-2 project alone. In the industrial background were the tens of thousands of workers needed to produce rocket fuels, metals, trucks, instruments: the whole vast army

required for industrial and logistical support of the V-2 programme. In one great underground factory alone, the Nordhausen works, 30,000 workers with 25,000 machine tools completed 30 rockets daily. Eventually, some 12,000 V-2s were manufactured.

Germany launched her first successful V-2 rocket from the sprawling research centre at Peenemünde on the Baltic, on October 2, 1942 (it was the third V-2 rocket to be launched), which continued on to crash into the distant target area of Pomerania some 170 miles away. Success and failure marked further launchings of the new, complex missiles. Finally, in the firing series of rockets No. 20 through No. 120, only 20 of the missiles failed, mostly because of mid-air disintegration, and 80 performed well.

Hitler bestowed emergency priority on V-2 production in 1943. More than once intergovernment politics nearly halted production and development. Immediately after Hitler's 1943 production order, for example, Himmler and army staff officers were waiting for a promised V-2 demonstration. Instead of performing as anticipated, the rocket struggled 450 feet into the air before careening back into the ground in a tremendous detonation of several tons of liquid oxygen, alcohol, and high explosives. Considerable persuasiveness on the part of the Peenemünde project leaders was required to make Himmler change his mind and allow production to proceed.

Some 4,300 of these giant rockets were eventually launched against Western Allied targets between the first combat launching on September 8, 1944, and the envelopment of all launching sites by British and American armies. London and Antwerp bore the brunt of the attack; of the 2,000 rockets which crossed the English Channel, only 1,230 smashed craters in London itself.

Some indication of the tremendous extent of German rocket activity is to be found in the number fired against Allied targets

along the English Channel coast and in England. In the postwar phase of American rocket research, only 68 V-2 rockets have been fired over a period of several years. In less than six months the Germans launched 4,300 of the V-2s against enemy targets in addition to other combat launchings, test flights, and initial development launchings.

When the war in Europe finally ended, the former solidarity of the Allied nations swiftly crumbled as intelligence teams raced into the German heartland to rescue such V-2 rockets and parts as remained intact. Not only were the rockets hauled off as prizes of war; technicians and scientists were taken along as well. Blueprints in the hundreds of tons, industrial data, production information, technical data on fuels, instruments, firings, performance, etc., were rushed to the United States, to England, and to Russia. France made some feeble attempts to obtain V-2s and eventually fired a few of the missiles. The British fired two V-2s at Cuxhaven in repetitions of combat launchings.

When the 100 or so V-2 rockets were trundled across the United States to warehouses and laboratories where they were eventually rebuilt for test launchings, they were accompanied by the many years of German research and experimental data. Not only were the written facts available to assist the American engineers; America also had most of the German scientists who had given birth to the original German rocket programme and carried its development along until Allied success brought an abrupt halt to all activities of the Third Reich.

The characteristics of this V-2 rocket, which imparted so much to the American programme of rocket research and in reality formed the major portion of American rocket activity until recently, are described in the following table:

Descriptive table: V-2 (*for range of* 189 *miles*)

Maximum velocity	3,466 m.p.h.
Impact velocity	1,800 m.p.h.
Height of trajectory	60.3 miles
Total elapsed flight time	3 mins., 40 secs.
Weight unfuelled	10,300 pounds
Weight fuelled	28,380 pounds
War head (60% amatol, 40% metal)	2,230 pounds
Alcohol	8,304 pounds
Oxygen (liquid)	10,800 pounds
Other fuels	350 pounds
Length	46·05 feet
Width (across tail fins)	11·69 feet
Diameter	5·41 feet
Fuel capacity	2,500 gallons

The American rocket research programme began nearly eight months before the first V-2 crashed into London. In January of 1944 the United States instituted its first high-altitude rocket projects, using a series of powder-fuelled missiles known as the "Private" series. Strictly research rockets, they were designed to help ferret out the answers to problems posed by fuels, ignition, duration of firing time, launchings with and without booster rockets, in-flight control, and many other aspects of missile control and guidance. Each "Private" rocket carried a small number of instruments which telemetered behaviour of the missile in launchings and during its ascent.

The "Private" series of missiles, and the research programme employing these missiles, was an effort insignificant when compared with the stupendous endeavour of the Germans. The American

programme did not have any specific long-range development goal at its inception. Several months after the programme began, however, it blossomed into a research effort with signs of promise when the Army Ordnance Department forwarded requests for a rocket capable of carrying atmospheric exploration instruments to a height of at least 100,000 feet, or just over 19 miles.

The "Private" rocket series with its maximum range of about 12 miles obviously was not capable of meeting these performance demands. Engineers were called upon to produce a missile which would achieve the desired goal. Thus was born America's first true high-altitude exploration rocket missile, the WAC-Corporal, 16 feet in length and one foot in diameter. Propelled by liquid fuels rather than by powder of limited performance, the WAC-Corporals weighed 665 pounds, without the large powder-fuel booster rockets used for take-off, at launching.

During September of 1945, less than a month after World War II came to a final close, the first WAC-Corporal was launched from the hot sands of the New Mexico desert at the White Sands Proving Grounds. Rocket engineers were enthusiastic. Instead of merely meeting demanded specifications, the WAC-Corporals soared to 43½ miles in a vertical ascent, more than double the altitude performance required.

By early 1946, with additional firings of WAC-Corporals, the American rocket programme was beginning to develop momentum. In designing, constructing, and firing the early powder-fuelled and the subsequent liquid-fuelled test rocket missiles, engineers acquired a first-hand education in the development and control of missiles which would eventually develop into globe-circling weapons. Later, space-travel enthusiasts promised, the early work at White Sands

and other proving grounds would result in the first orbital rockets, the space satellites, and at long last the first space ships to circle about and land on the moon.

It was natural that another liquid-fuelled rocket should meet the increasing demands for a missile with performance superior in payload and heights to the WAC-Corporal. This proposed missile was required to be superior to the WAC-Corporal, yet cost restrictions demanded that it remain within feasible budget limitations. It was impracticable to employ V-2 rockets for this increased activity in high-altitude exploration since they were limited in number; there would be little purpose in instituting a production programme to build additional V-2s when a major part of the American research activity was devoted to gathering data sufficient to develop rockets superior to the wartime German weapon.

The Aerobee was then designed and rushed into production. It was tried for the first time during November of 1947, after the V-2 programme was well under way. Specifically designed for upper-atmosphere research, as was the WAC-Corporal, its similarity ended there. Capable of reaching a height of more than 71 miles, it accommodated an instrument load of 154 pounds against the 25 pounds of its predecessor. This pencil-thin missile was 18·8 feet in length and only 1·25 feet in diameter. As in the WAC-Corporal, a powder-fuel booster rocket launched the Aerobee on its way; 19 miles above the earth, the Aerobee was moving towards outer space at a velocity of 2,790 miles per hour.

The Aerobee provided, as did the WAC-Corporal, a relatively inexpensive rocket instrument for research in the physics of the upper atmosphere. It provided the United States Navy and its contractors, and the other services which later adopted it, with experience in the practical handling, servicing, fuelling, launching, and tracking of high-performance liquid-fuel rockets. Engineers and technicians accumulated advanced engineering experience and practice in the design, testing, and launching of the rockets which were not only experimental missiles but potential military weapons. The Aerobee was used more extensively than the smaller WAC-Corporal, and provided experience not only in launching from towers with booster rockets, but also in launching techniques from ships moving at sea. This latter development, also employed in tests with the V-2 rocket, obviously is paying great dividends in the present guided-missile warships of the United States Navy, and with potential guided-missile-launching undersea craft.

In later Aerobee models, attempts were made to retain the missile intact after it had spent itself during the upward climb and returned to the desert sand. The rocket was exploded into two parts as it reached the peak of its climb. By breaking up the entire missile, the two separated parts became aerodynamically unstable and tumbled to the ground, instead of the whole rocket hurtling down in a plunge of great speed, its trajectory aided by the external fins. The split Aerobee sections struck the earth with an impact velocity of only 150 feet per second, allowing intact recovery of many instruments and photographic plates carried by the rocket. The final step towards instrument recovery came about when a high-speed ribbon parachute was fitted to the rocket to lower the entire instrument section without damage.

In 1949 the U.S. Air Force adopted the Aerobee. It inaugurated an advanced programme for investigating the composition of the atmosphere at altitudes 75 miles above the earth. The first series of firings commenced at Holloman Air Force Base, Alamogordo, New Mexico, not too far from the historic site where the first crude atomic bomb gave birth to a new but brief-lived star. The new rocket programme

supplemented existing Army, Navy, and Air Force upper-atmosphere studies, utilizing the German V-2 rockets launched by the Army from the White Sands Proving Grounds.

The Aerobee programme, like other rocket-launching projects, was not exclusively within the military domain, although control rested with the armed forces. Leading educational and research institutions from every part of the nation were involved. A score of priority research projects, military and civilian, were aided by the findings of electronic recording instruments placed in special compartments of the slim Aerobee. Each research organization concerned was responsible for providing the full instrumentation for one or more of the rockets during the two-year launching schedule, completed in 1951. It will require many years to evaluate properly all the information obtained from the series of Aerobee firings. Among the beneficiaries of such data is, for example, the Air Force; its engineers are aided in evolving improved guided missiles, in determining the relation between solar activity and weather changes, and in studying basic atmospheric information for the military guided missiles which have for many months been rolling off the production lines.

There is little question that, in the rapidly growing American rocket research test programme under way during the first few postwar years, the leading role was played by the V-2. Before we review the developments of the V-2 test project, it should be mentioned that many other rocket missiles were launched as part of the research programme. Among these were the Consolidated-Vultee MX-774, a missile of intermediate size designed for flights as high as 100 miles above the earth, and the North American Test Instrument Vehicle NATIV, limited in performance but greatly rewarding in technical knowledge gained from its flights. These missiles and others were

designed, built, and launched essentially as interim steps in the programme which continued to accumulate valuable missile design and performance data.

By July of 1945, several weeks after the European fighting came to a halt, 300 freight-carloads of V-2 components had been shipped to the White Sands Proving Grounds. While the first American missiles were being launched in the early stages of the postwar research programme, engineers carved a tremendous static-test stand in the side of a cliff. Essentially a heavy concrete shaft with massive clamps gripping the V-2 in place, it permitted maximum firing of the V-2 motor, enabling technicians to observe operation of its parts and to determine exact motor thrust. The first full static-test firing was made on March 15, 1946.

The American technicians encountered difficulties before the V-2 ever left the ground. The German technicians who had been brought to this country to assist in V-2 firings were nonplussed by the first major problem which confronted them, that of assembling the rocket parts into a completed missile for firing.

This was more of an obstacle than it would seem to be. The rocket components shipped to White Sands were collected from all parts of Germany, and two of perhaps a hundred missiles were assembled from originally matched parts. No specific instructions for assembling rockets from this conglomeration of parts existed. Some parts had deteriorated so badly that it became necessary to machine new components.

On April 16, 1946, the first V-2 launched in the United States lifted itself off American soil and thundered heavenward. Technicians had prepared the rocket for its flight as though it were a matter of life or death. Every last precaution had been taken. Nineteen seconds after launching, disaster struck when the No. IV fin ripped

loose. Radio controls immediately cut the motor operation; the V-2 crashed a few seconds later, after attaining an altitude of only 3·4 miles.

When the V-2 firings were completed, with a total of 68 actual launchings, it was evident that the over-all performance of the rockets launched in America was better than that which the Germans normally attained in their field operations. Of the 68 firings, 45 proved completely successful, a percentage superior to that anticipated by the German V-2 technicians. The organizations and personnel responsible for the V-2 firings were more than satisfied. They had completed a programme plagued by aged rockets and deteriorated equipment. The last V-2 was fired in June of 1951. Of the 45 successful firings, no malfunction of equipment or the rocket manifested itself in 32. Useful test data were gathered from the remaining 13 launchings, although performance was below the capabilities of the V-2.

The five-year V-2 firing programme consisted of more than launching rockets and analysing information telemetered back to earth from the instruments borne aloft. Rockets were fired on the basis of a detailed, carefully considered plan involving the recommendations of hundreds of scientists and technicians. The signal success of this project stems directly from the activities of an organization dubbed the "V-2 Panel"; representing military, research, and commercial personnel and agencies which required information obtainable only through V-2 firings, they nursed the programme along to assure that every avenue of obtaining data would be utilized.

It was this panel which controlled every V-2 firing from White Sands. Each rocket, months before firing, was assigned to a participating scientific group; the group represented, on the average, a wide assortment of various research organizations pooling their

resources to obtain data from the rapidly dwindling supply of rockets. Once assigned, the V-2 became the "exclusive property" of the group. Technicians serviced the great missile with infinite care, preparing it for its brief surge of life. Each group involved with a V-2 accepted the responsibility for instrumenting the missile, launching the rocket, and making available the information obtained.

One of the outstanding results of the entire V-2 programme, beyond the initial upper-atmosphere studies, was that it was learned how to fire two-stage rockets successfully. The firing on February 24, 1949, which broke all records, was only one Project Bumper launching. Bumper sent into the skies eight two-stage rockets, not only in vertical flights, but missiles which established new long-range distance records in *horizontal* flight.

Prior to the Project Bumper launchings, knowledge of two-stage, or two-step, rocket performance was only theory. No matter how extensive that theory, it was not fact until a multistep rocket actually exhibited its capacities. Thus the Bumper phase of V-2 firings gave the United States a jump in the development of giant rockets which are capable of establishing orbital satellites about the earth and, of course, leaving the earth to make a successful moon trip.

Experiments were made to increase knowledge on the problems of heat transfer; the tremendous velocity of the V-2 rockets caused parts of the missile to glow cherry red as the V-2 returned to the atmosphere after reaching its zenith. Aerodynamic projects received a tremendous impetus from the hurtling V-2s which, through camera and instrument findings, simulated passage of future aircraft and missiles through and beyond the atmosphere.

This exploration of the upper atmosphere by V-2 rockets

contributed more to knowledge of conditions high above the earth than any other research programme. Detailed studies of specific conditions were possible, since the V-2 remained at great heights, even though moving rapidly, for several minutes after firing. The actual gaseous components of the upper atmosphere were studied by scientists under ideal conditions; sampling bottles carried aloft by V-2s and recovered after the flights enabled scientists to conduct tests of the upper atmosphere in well-equipped laboratories. Mass spectrometric equipment installed in the capacious V-2 instrument compartment supplied other important findings.

Carrying its load of instruments up to 128 miles above the earth, the V-2 made it possible to conduct direct measurements of ionization in the upper atmosphere. Study of conditions on ion densities in the E-1 and E-2 layers of the upper atmosphere, impossible prior to the V-2 programme, was accelerated. One certain result from this test phase is the promised performance of future radio equipment for missile radio-control purposes. Expanding the existing research programme studying the mysteries of cosmic and soft X-ray radiation, V-2s carried aloft not only measuring instruments but insects and animals. The smaller Aerobee was also employed for this purpose.

With the V-2 beyond the atmosphere, or at least beyond any interference from the atmosphere, exact corona temperature studies of the sun were made with unparalleled accuracy. The earth's albedo—its ability to reflect sunlight and moonlight—was observed with great accuracy. The earth's magnetic field came in for close study, with a considerable increase in the knowledge of this subject.

Experiments were made with new parachute designs and parachute-operating techniques. These were not intended to lower V-2 sections or the entire rocket, but to provide the necessary data which

will enable future rockets to be lowered from great heights and at great speeds. Temperatures generated in the atmosphere by the V-2's velocity melted conventional nylon parachutes.

Before we can ever hope to establish large, manned space satellites, we must increase our knowledge of meteor and meteoric dust conditions high above the earth. The V-2 opened this phase of research by actually measuring the atmosphere's meteor-dust content. With all noise-producing parts of the rocket shut off, sensitive instruments transmitted noises to the ground. Observers could hear the pinging sounds of collisions between meteoric dust particles and the V-2 surfaces! Other V-2s carried special controls which, at altitudes at which the rocket was beyond any noticeable atmosphere, uncovered highly polished sheets of metal. Meteor-dust collisions were measured on these plates. Back in the hands of astronomers and other scientists, they told a graphic picture of the problems to be encountered by future rockets at altitudes up to 110 miles.

Experiments preparing the way for communications in space between earth stations and space ships were conducted. For the first time black-and-white and colour pictures of the earth taken from great altitudes were obtained. A 275-inch television screen, 15 lines of which were used to transmit instrument data and the remainder to send pictures, was installed in V-2s by the Air Force as a preparatory step for developing space-ship and space-satellite communications equipment.

The greatest insight into rocket functions was obtained through misfires: when something went wrong and the V-2 crashed or was destroyed by remote control. Exhaustive studies of the failures usually provided exact information as to what caused malfunction, and steps could be taken to eliminate such weak spots in the design of future missiles.

A V-2 rocket was launched from the flight deck of the carrier U.S.S. *Midway* on September 6, 1947. Only through the actual firing of the V-2 from a moving ship could the potential success of projected missile-firing warships be determined. Factors to be determined by the live firing included fuelling, servicing, and launching a missile of V-2 size aboard a ship; whether or not the V-2 could be launched successfully by a moving vessel; accuracy of a shot from a vessel at sea; and the time necessary for the aircraft carrier to return to normal flight operations.

The immediate benefits of having the V-2 available for detailed study in design, construction, launching, and theory of operation were quickly realized. V-2, of course, provided the major instrument for many phases of the postwar research programme, certain phases of which were based on WAC-Corporal rockets, and finally, to a much greater extent, on the superior Aerobee. Even this missile, however, left much to be desired for extreme high-altitude operations, such as the regions above 80 miles where the V-2 soared.

And so was born the Viking, designed to climb to altitudes beyond that which even the V-2 could attain. The instrument payload, however, did not quite match that of the German missile. The Viking accommodated from 100 to 2,000 pounds of instruments; with the latter and heavier instrument weight, its performance fell short of its German contemporary.

Viking engineers claimed that with minimum payload the new rocket would ascend to 238 miles above the earth at a velocity near to or exceeding 5,000 miles per hour; accommodating a maximum payload similar to that of the V-2, it would be able to climb to only 85 miles.

Although as tall as the German rocket, Viking is much slimmer. Design advantages over the older V-2 allowed a lesser take-off gross

weight: 9,500 pounds for maximum performance, and 11,400 pounds with maximum payload. This was attained with a rocket motor not nearly as powerful as that of the V-2, the Reaction Motors unit which generated 20,000 pounds of thrust.

Some of the design improvements of which Viking boasted included an alcohol fuel tank built as an integral part of the rocket fuselage, rather than an individual tank separately constructed and then placed inside the missile. This arrangement, which reduced the chance that alcohol fuels and oxygen might mix inside the rocket in the event of fuel-tank rupture, thus minimized greatly the opportunity for explosions such as had destroyed a number of V-2s. It allowed a considerable reduction in over-all rocket weight, and thus enhanced performance.

To transport the larger V-2 rocket a special Meilerwagon was required; this is a large "truck bed" on which the V-2 is cradled. With the Viking, a tubular frame with two wheels is fitted to the after end of the rocket and a single wheel is placed under the rocket nose; it is then simply towed to the launching site, where a hoist lifts the rocket to a vertical position.

The V-2 design placed four carbon vanes in the stream of the flaming rocket exhaust; by tilting these vanes, the V-2 trajectory was changed in flight. Not only did the vanes restrict performance by causing a drag in the exhaust; if they broke off completely, the stability of the rocket was threatened. In a number of cases when this occurred, the V-2 veered off at odd angles; ground control either cut the rocket motor, causing the missile to crash, or the V-2 careened into the ground. In the Viking the stabilizing mechanism has been completely redesigned. Stabilization is achieved by causing the whole motor section, mounted within a gimbal ring, to swing in the desired direction. Thus the troublesome carbon vanes have been

eliminated completely, and motor efficiency is considerably improved.

Since a large missile of the Viking or V-2 category is a complicated affair, with the success of the entire unit resting at times upon perfect performance by every component, it is inevitable that "luck" should play a part in determining successful launchings. A little piece of wire which fails, for example, when the rocket is in its critical early take-off period, can mean failure of the entire launching and premature destruction of the rocket.

Every new rocket thus runs into difficulties of design in its early development stage. To the despair of its army of engineers and technicians, the Viking seemed to draw trouble as a bright light attracts moths. Before the first launching took place in May of 1949, the firing date had been postponed several times. During the first Viking static tests at White Sands, difficulties were encountered in the electrical system, the motor, the pressure lines, the insulation, the intricate control system, and other parts.

When the Viking was finally launched on May 3, 1949, the automatic controls misbehaved and cut the motor off before the rocket could achieve the best performance. It attained a maximum velocity of 2,250 miles per hour, and climbed to a peak altitude of 50·5 miles. Viking No. 2 was fired on August 26, but the missile stood on the launching-pad and failed to rise. When Vikings No. 2 and No. 3 finally achieved flight, motor failure and lack of control caused both missiles to be restricted to respective altitudes of 33 and 50 miles. Viking No. 4, fired from the deck of the U.S.S. *Norton Sound* in the Pacific Ocean in 1950, attained a speed of 3,600 miles per hour and a peak altitude of 106·4 miles. The fifth rocket, launched from White Sands, climbed to 107·3 miles. In a night launching No. 6 failed to reach 100 miles.

It was not until the seventh Viking rocket was fired that performance finally surpassed that of the V-2. This missile established a new record for single-stage rockets by climbing at 4,100 miles per hour, and reached a height of 135 miles above the earth. Viking No. 9, the latest missile released, substantially redesigned and weighing 15,000 pounds, matched the height record of the seventh Viking fired, although its velocity was only 3,900 miles per hour.

We are not ready yet

It appears obvious, on considering the development and performance of our latest rockets, that the activity of the past nine years has been essentially preliminary. Aside from increased knowledge of rocket theory and operations, we are little more advanced in 1954 in the possession of large rockets than we were when the V-2 ushered in a new era of rocket development nearly 12 years ago.

The Viking rocket, of which less than ten have now been constructed and fired, represents some engineering improvement over the V-2. The former's performance, however, can hardly be described as a notable advancement over the German product. Thus, after more than a decade (of which eight years have seen active American experimental work), we possess only the Viking as concrete evidence of our progress towards space travel.

The record-breaking Project Bumper two-stage V-2/WAC-Corporal represented only the field testing of a theory already decades old when it soared to new heights in early 1949; the V-2 was certainly not a new missile, and the WAC-Corporal was hardly superior to any one of several German wartime rockets. In this two-stage Bumper we fired a missile which, while establishing new velocity

and altitude marks, was inferior in performance to working German projects scheduled for launching in early 1946.

The statement of such facts appears to dash cold water on the aspirations of those who entertain the belief that space travel is "just around the corner." Indeed, such negative conclusions might even be interpreted as a criticism of the message of this book, which implies strongly that space travel *will* become a reality in the very near future. Such is not the case. It is essential that the purpose of the programme be appreciated before the results of the American rocket and high-altitude research programme of the last nine years can be properly appraised.

The expenditure of many millions of dollars in firing hundreds of rockets since 1945 found its only justification in the fact that such a programme was vital to national security. The wartime V-2 rocket was a dismal military failure, not through any limitations of the missile, but because of the political decisions affecting its control and its eventual use. Although it was a failure, the V-2 made it glaringly apparent to military strategists that the "handwriting was on the wall" for strategic air power. There was little doubt in the minds of those men who are responsible for the protection of the United States that, within a decade or two after the last war, the long-range intercontinental bomber would become a vulnerable target for hostile anti-aircraft guided missiles. That meant that another means for hurling destruction at an enemy's industrial centres—the Achilles heel of any modern power—must be found. The long-range rocket, an improvement of the pioneering V-2, was the only answer.

Although the V-2 represented a tremendous advance over any previous rocket and was considered the second greatest technological achievement of World War II, second only to the atomic bomb, its limitations in range demanded that extensive research develop

a superior missile. Eventually, that missile was to become a truly intercontinental rocket which would replace altogether the obsolete long-range bomber.

There was far more to the problem than merely effecting an increase in range. The inaccuracy of the V-2 was such that, although it was satisfactory for launching against such a large target as the many hundreds of square miles which comprised the city of London, it proved woefully inadequate against smaller military objectives. A study of wartime V-2 firings indicated clearly that there was ample room for improvement in the rocket's operational efficiency. We could hardly afford to place scarce atomic-bomb war-heads in rockets which would malfunction in every three out of ten launchings!

It was necessary to improve the rocket as a whole. During the war Dr. Wernher von Braun objected strenuously when Hitler finally placed the V-2 in mass production; it was von Braun's contention that the missile required further technical development and would therefore fall short of the performance which its potential design promised and which Hitler demanded prematurely.

Thus, American engineers set their sights on a missile which would become the major weapon of intercontinental warfare, a rocket capable of reaching across an ocean, with pinpoint accuracy, enabling it to drop within one mile of its intended objective. The development of an intercontinental missile was the justification of our postwar research programme. A programme of this nature fortunately allows the integration of many other vital research efforts simultaneously with the development of the missile in mind. The two go hand-in-hand, actually, since upper-atmosphere research could hardly be carried on without the large rockets.

With the rockets available in 1945, and the limitations of our

actual working knowledge, it would have been sheer waste immediately to begin the construction of large missiles. To insure the effectiveness of such a missile, we could do little more than duplicate the existing V-2, a rocket unsatisfactory in its final form. The only sensible thing to do was to use such V-2s as were available for continuing rocket research, and to build a minimum of only essential rockets. These latter would incorporate known methods of improving the V-2, but would exist only to supplement the V-2 programme and would not represent a separate research endeavour. That was the course of events. We undertook over a period of several years to squeeze every bit of rocket theory and knowledge out of the V-2 firings, and later the Viking shots. Not only did such a programme fulfil immediate rocket-research and development needs, but it was carried out at minimum cost and with the best results.

The reader may ask at this point: "Just what does all this have to do with space travel?" The answer is: Everything. The many V-2s, Vikings, WAC-Corporals, Aerobees, and other research missiles are the forerunners of tomorrow's space ships. Each rocket fired since 1945 has contributed immeasurably to the development of the first space ship actually to leave the earth.

Through this research effort, we have learned the proper method of manufacturing and storing great quantities of rocket fuels, a gigantic task in itself. The fuelling of large rockets is a complicated procedure, attended by disastrous consequences if not conducted properly. We have learned which fuels give maximum performance, and we are painfully aware that a successful effort towards space travel demands improved and more powerful fuels.

The construction of the rocket itself means new industrial and manufacturing techniques. We now have a good idea of what metals are best suited for rocket manufacture, what stresses must be met,

and what thickness a metal must be to withstand the searing heat of air friction.

New motor designs, improved pressure systems, remote- and timed-control mechanisms, instrumentation compartments, transport of rockets and rocket parts, firing techniques, insulation procedures, electrical systems, pressurization—these categories and a thousand others no longer pose immense problems for the men who handle the great missiles. While at this particular moment we do not have the actual rockets which will be hurled into space to enter precise orbits as the first man-made satellites, their instruments constantly telemetering vital information back to earth, we have more than a good idea of how to build those initial robot space ships. We are no longer working in the dark. Developing the high-priority intercontinental guided missile is, in essence, developing the first space ship. The Bumper two-stage missile of 1949 actually hurtled into empty space. Building a rocket capable of the velocities necessary for intercontinental warfare means that we simultaneously build a rocket which, perhaps with some modification, can leave the earth and circle about this planet indefinitely.

Many phases other than rocket development have benefited from the improvement of our missiles. Meteor conditions are no longer a feared enigma; the study of physiological reactions under conditions of zero gravity is becoming a science rather than mere theory; communication in space has emerged from the paperwork stage; and many other problems have similarly been solved.

The initial probing into the field of theory and basic operations is just about completed. We know what must be done and how to do it.

2

Robots into Space

We are but one step short of the conquest of space.

Although not yet standing tall and powerful on its launching-pad, the first space ship may be said to "exist" on the drawing-boards of thousands of rocket engineers. Its design, now awaiting integration into a single unit which will break free of this planet, lies in the storehouse of working knowledge accumulated in the last 12 years.

Man's first space ship will never reach the moon. It will boast no well-equipped control cabin, for no man will ride within its steel frame. It will never return to earth, yet its brief surge of life will not permit it to travel any great distance from this planet.

The first space ship will be a robot. Flaming rockets will hurl it several hundred miles above the earth into a permanent orbit, where it will sweep silently through space about this world like a sleek, miniature steel moon.

Just how far are we from actually building and launching this long-awaited vessel? Rocket engineers entertain the belief that, since the orbital satellite poses engineering problems of a magnitude not much greater than those of existing large rockets, creation of this space ship can be a matter of the very near future. They contend that vigorous development of this project could result in establishing

the unmanned, instrumented satellite about the earth within five years' time.

Dr. Wernher von Braun best sums up the situation in this statement: "Even slight extensions of present techniques could set a small, unmanned missile circling in an orbit just outside the atmosphere." Von Braun's inference is unmistakable. By constructing a multistage rocket along the lines of existing tested missiles, we can place the instrument satellite in its orbit about the earth any time we wish to do so.

Another school of thought among rocket engineers differs sharply with von Braun's contentions. These men, engaged, like von Braun, in the field development of America's guided missiles, point out wryly that we are dangerously behind schedule in our missile programme. They state with justifiable anger that, after the eight years of research and development which have absorbed nearly three billion dollars, we are only at the point the Germans reached a decade ago. In pointing out that satellite missiles are still "a project for the future," the less optimistic rocket engineers emphasize that we have no volume production of any major guided missile. Even intercontinental weapons are still a dream and, in their opinion, far from reality. They quote facts to bolster their contentions. Missile men are bitter about allocations which represent but a miserly portion of defence funds. Ten obsolescent Convair B-36 bombers cost more than the entire American Air Force allocations for guided missiles in 1953!

Other missile men, fed up with duplication of effort and security measures which prevent research groups from learning of the progress of "rival" groups, refer to the five-year record of 68 V-2 firing with an "absolute" reliability of less than 50 per cent. They compare this figure to German V-2 combat use, where the Germans

achieved a 75 per cent reliability with the same rocket, and under more trying circumstances.

Common sense is lacking in many phases of missile development. German industry built the V-2 on a mass scale with the equivalent of cold-rolled steel. Inexpensive and adapted to mass production procedures, it made possible a missile production programme at minimum trouble and expense. American military specifications demand the use of stainless steel on expendable missiles, a ridiculously costly, wasteful, and troublesome practice.

There are other complaints. Engineers point to the single concentration of brain power which characterized Peenemünde; although this research centre ran into its own governmental and political difficulties, it was backed up by a solid organization of schools and subcontractors which furnished knowledge or equipment as the need arose and Peenemünde demanded. By contrast, the United States has 25 active missile projects divided among nearly 50 major scientific or industrial organizations. These in turn are broken down into airframe plants, engine plants, component plants, and various laboratories and subcontractors. All this, missile men moan, only confuses the development programme. Missile engineers complain that this diversified number of organizations is now producing little to justify the expenditure of three billion dollars. Even though production is under way of the Army's Corporal E rocket, a basic research missile, slightly more advanced than the V-2 and suitable for surface-to-surface bombardment, this represents disappointingly little success for the expenditure of so much effort. Furthermore, there is little difference between the Corporal E and the Naval Research Laboratory's Viking rocket, used only for research purposes.

Other missiles designed to do other jobs have been developed. But missile men who regard space satellites and space flight as a

matter for the far future insist that there is no escape from the conclusion that, with the exception of a few such rare shots as the 1949 Bumper firing, we are still earthbound.

The advocates of space travel admit this. They also insist that it represents only a partial picture and that the satellite is feasible within the time specified. Von Braun, for example, is certainly well acquainted with the difficulties of missile production, since he was the technical director of the German V-2 project. He points out the problem posed by the intricate details involved in building the wartime V-2, stressing the fact that in the transition from the first successful test V-2, the third fired, to the final production model, 65,000 drawing modifications were required. Members of the von Braun school of thought have other ammunition to support their claims. Disregarding the group of engineers, whom they consider unduly pessimistic, they point to the uncompleted German wartime A-9/A-10 project, planned for actual firing some time in 1946.

Towering 110 feet above the ground and weighing 86 tons, the A-9/A-10 bumper rocket was designed for a maximum range of 3,150 miles. At *Brennschluss*, the final moment of motor operations, the second-stage A-9 rocket would be moving at a velocity of 6,300 miles per hour 100 miles above the earth! With modification, this bumper missile could have added a third stage, firing it into a permanent orbit about the earth. The engineers who produced the V-2 had no doubt as to the ultimate success of the A-9/A-10 venture, which is of a magnitude beyond present American projects. There is, of course, the possibility that security restrictions prevent public knowledge of a similar project in the United States. It is not beyond belief that such a bumper missile is under construction or already exists.

Not even the most optimistic engineer would claim that construction

of the first missile satellite is a simple matter. The reliability of any missile is an all-important factor, yet the complexity of missiles gives rocket engineers prematurely grey hair. On the positive side, however, is the fact that, while the proposed missile satellite represents an advance over existing missiles calling for extensive engineering labour, it remains basically a missile without additional demands for personnel equipment and space factors. As von Braun said, it is a matter requiring "slight extensions of present techniques."

The Robot into Space

The establishment of an unmanned, instrument-bearing rocket in a satellite orbit will be the first step in the actual conquest of space. In its sweep about the planet, the satellite will provide scientists, through telemetering instruments, with the answers to thousands of engineering questions, all vitally necessary to the design of manned space ships, which cannot be answered with available research missiles.

The first consideration for the missile satellite is practicability and reliability. Once the giant multistep missile pours fire from its rocket motors, it is beyond our capacity to return it to earth in the event of malfunction and reprepare it for its journey into space.

To be successful, it *must* operate perfectly. There are no alternatives, and not even one mistake is allowed the launching crew once the firing-switch has been pulled. The one mistake is as bad as a hundred; quick destruction of the missile is the inevitable result.

Maximum possible reliability is a prerequisite for the first successful missile satellite. Each new piece of equipment, from radio instruments and the rocket motors down to valves, pipelines, and

gaskets, must be tested and re-tested until its reliability is close to absolute.

One of the first requirements is a rocket motor superior in efficiency to present power plants. The development of better and more powerful rocket motors has plagued the missile engineers for years. Any engineer can build a rocket motor and make it work; strange as it may seem, however, the theory of combustion within the motor still exhibits a great many unknown factors. We do not know nearly as much as we would wish about these powerful sources of energy, which is the reason why manufacturers have encountered so much difficulty in developing superior power plants.

Only extensive research can produce better motors, chemical fuels, high-temperature metals, ceramics, and improved methods for cooling the fiery inner walls of rocket motors. Many an engineer believes the major stumbling-block to a rapid conquest of space is the lack of sufficiently powerful fuels. In our attempts to overcome the great pull of the earth's gravity, we are endeavouring to run a truck uphill with motorcycle power.

It is immaterial whether the missile satellite is established within a decade from now or must wait, for technical or monetary reasons, for the passage of several decades. However, rocket engineers may disagree on the time elements involved in realizing satellites and space travel, but they *do* agree on the basic scientific principles involved. The sum of that agreement is that it is only a matter of time before we launch the first unmanned space ship beyond the earth.

In all probability earth's artificial satellite will be a three-step rocket. This multistep missile will have a main power boost which serves to hurl steps two and three beyond the atmosphere before it burns its fuel and before step two, supporting the third and final

step, is fired. The second step, its motors operating once the greater part of the atmosphere has been left behind, swings slowly in its ascent from the perpendicular until it is moving forward in a plane horizontal to the earth's surface. The third stage, a sleek missile without external tail fins (unnecessary since it will not fire its motor until it is in space, where tail fins are without an atmosphere to react upon), fires its single motor until it moves into its planned orbit, to remain there for all time.

L. R. Shepherd, Technical Director of the British Interplanetary Society, in a presentation at the Symposium on Satellite Vehicles at the Second International Congress on Astronautics, held in London in 1951, states that a three-stage rocket could establish a satellite in an orbit 310 miles beyond the earth. The initial mass of the multistage rocket would be about 300 tons for each ton of useful payload sent into the orbit. Even this figure represents a notable advance over current missiles, since the necessary velocities are almost half those required for an earth-to-moon flight, or in the vicinity of 15,000 miles per hour for the third and final stage.

An orbit might be established 346 miles beyond the planet; here the satellite will swing about the planet once every 96 minutes, making 15 complete revolutions per day. Its velocity will be 4·71 miles per second, or just a little less than 17,000 miles per hour. At a distance of 470 miles from the earth, a satellite would complete a revolution about the planet once every hour and three-quarters.

In the proposed three-step missile, it will not be necessary to equip the third and final step, the satellite itself, with guidance equipment. The first step, boring upwards through the atmosphere, and the second step, swinging from vertical to horizontal flight, perform that function. The curved path, so necessary for step two, completes the guidance mission and places the missile in its orbit, aligned on the proper tangent relative to the earth's surface.

It is necessary to control the final step, but in a different way. What controls it must fulfil the requirements of inertia control, if it is to prevent the rocket axis from "wandering." This could be accomplished with a simple gyroscopic arrangement, in conjunction with exhaust vanes placed to act upon the fiery gases streaming from the motor orifice. A better arrangement might be a "pivoting motor" (*i.e.*, Viking) to correct pitch and yaw during the final power period. This latter propulsion phase is necessary to bring the satellite to its orbital velocity. Once, however, the third stage has separated from the second stage, all guidance control will be broken off. The third-stage missile would then be at the required height above the earth, moving at the precise velocity to keep it at that height indefinitely. At the moment the third-stage power was abruptly cut off, the space satellite would be a reality.

During that part of the rocket's ascent when the first stage hurtles upwards, automatic controls manipulate motor operation with hair-trigger precision. One would normally suppose that before a succeeding step in the multistage rocket was fired, the booster step would have exhausted every last ounce of fuel, in order to obtain maximum velocity and altitude. Actually, such is not the case. If the rocket is to work properly, automatic firing-controls silence motor operation before all available fuel has been consumed by the roaring motors. If the motors are left operating until all fuel has been burned, the consequence is that it is nearly impossible to obtain a smooth cut-off of power. The end result is that the rocket loses its "balance." In the case of a multistep rocket this could be disastrous.

The V-2 provides a good example of the need for smooth motor cut-off. Assume the rocket is nearing the end of its powered ascent period, climbing at approximately 3,600 miles per hour at a height of 20 miles. There are a number of burner cups in the V-2 motor; if

several cups continue to burn or sputter for even a second after the majority are silenced, the rocket is thrown out of balance by this uneven force. This does not, of course, affect the performance of the rocket; the V-2 is already at the 20-mile height beyond which the atmosphere no longer exerts any appreciable force against the large external fins. While the performance of the missile remains unchanged, its *attitude* in flight is altered.

The V-2 continues to coast towards outer space, its 3,600-mile-per-hour velocity gradually lessening as gravity tries to pull the rocket back to earth. Instead of hurtling heavenwards with the rocket axis perpendicular to the ascent, it may tumble end over end through the near-vacuum.

This does not affect the performance of the rocket in its attempt to gain altitude. Whether the rocket ascends with the nose up and tail down, or tail up and nose down, is immaterial, since there is no atmosphere to affect the rocket's movement. Even if the shot were made to attain distance with height, with a parabolic trajectory similar to that of an artillery shell except at take-off, once the rocket leaves the effective limits of atmosphere resistance, it may tumble end over end with absolutely no effect on its performance until it returns to the 20-mile height.

While the attitude of the rocket in flight is unimportant in a missile designed to do the job of V-2, this does not hold true for the multistage rocket. When the second of the three steps nears the end of its brief period of life, the rocket must not only be moving in its planned orbit, but the missile's angle of attack must be exact so that the third stage will be launched in the intended direction. Otherwise, even if the final stage were fired at the anticipated height and velocity, its flight could not be on the proper tangent aligned relative to the earth's surface, and the missile would eventually crash back to earth.

Once the third stage has reached its orbit, it can no longer be called a rocket. It is an artificial satellite, beyond the control of the men who gave it life. Since it is now moving in an orbit parallel with that of the earth, the moment that power stops the satellite falls back towards this planet. It falls with tremendous speed, at the same velocity with which it was moving when its glowing motor died out. Gravity has never released its hold on the satellite; for the period of time when the motors poured forth the necessary thrust, it was able temporarily to overcome gravity. Now that power is silenced, and the inescapable pull of the earth tries to reclaim the satellite. The satellite, however, is so high and moving with such velocity that the earth's spherical shape must be considered. Speeding forward, the satellite falls, but as fast as it returns to the earth, the surface of the earth drops away beneath the satellite so that it maintains the same distance and velocity from the planet.

We can best understand this phenomenon through another analogy. If we fire a bullet or rocket in a horizontal direction a short distance above the earth's surface, that projectile eventually returns to the earth. By increasing the velocity or the height of the projectile before firing, we insure that the projectile will travel a greater distance than on the previous attempt. For normal shells and short-range bombardment rockets, the fact that the earth is curved is meaningless. The earth is regarded as a flat plane. But when we rise high enough and can make our projectile rockets move fast enough, as we do in the satellite vehicle, then the earth's curvature is all-important. The satellite is moving at great speed, high above the earth. As fast as gravity drags it downwards, the earth curves away beneath it. In effect, then, the satellite falls endlessly about the earth.

Secure in its invisible path, the satellite's mission is just beginning. Never for a moment during its curving ascent through the

lower atmosphere into space was the multistep rocket lost to thousands of radar and theodolite tracking instruments. Electronic recorders absorbed and retained the invaluable data chattering instruments inside the satellite's nose sent back to earth on radio beams. Across much of the globe, instrument stations on land and at sea follow the motion of this newborn moon.

There are many ways in which this new moon will serve us. As it circles the earth, radar instruments will check and re-check its orbit, searching for possible deviations from the precise path long ago plotted by electronic computers. Any change in that orbit may be attributed to a number of factors, either familiar or unknown.

Satellite instrument-power problems must be solved before the expensive vehicle ever leaves the earth. We are sure of the instruments, but we are still searching for the means to power these instruments. If the usefulness of the satellite is to justify the expense involved, then a long operating life is a necessity. Batteries are of little help, since their span of life cannot be extended beyond a period of a few weeks. Nuclear power may perhaps be employed many decades from now when our knowledge of the subatomic world is sufficiently advanced to produce a small nuclear reactor. One encouraging aspect of this problem is the fact that heavy shielding is unnecessary, since the satellite is unmanned. Solar generators have been proposed, but the size limitations of the satellite seem to eliminate this possibility; it appears doubtful that such equipment could be built at this time to fit the dimensional limitations of the missile. Furthermore, our experience with this power source is insufficient to guarantee uninterrupted operation.

Any engineer familiar with the difficulties of automatic instrumentation can appreciate keenly the magnitude of the problem facing the satellite designers. Radio tubes burn out all too frequently on

the earth, where replacement is a simple matter. Premature failure of such equipment in space could destroy the value of the satellite. Broad experience with telemetering problems in postwar research rockets has contributed much to the final solution of this all-important phase of satellite design. The multiple-channel telemetering systems used in research rockets have been developed to a remarkable degree, and extended study in this field may solve the problem.

Except when in the shadow of the earth, the satellite will furnish scientists with a recording of the density of interplanetary gases, obtained through a continuous solar spectrum. Our knowledge of this subject is sure to be greatly increased, especially so since such spectrum readings will be obtained without interference from atmospheric secondary effects and secondary cosmic radiation.

Perhaps most important of all purely scientific bounties to be gained will be the increase in our knowledge of primary cosmic rays, with all the implications to nuclear physics and our further understanding of their character. Cosmic radiation constantly bombards the earth with stupendous energy. The celestial bullets which make up cosmic radiation come from "somewhere in space" and we may be able to determine their source.

Scientists already have some understanding of secondary cosmic radiation, the after effects occurring when cosmic ray particles collide with the atoms which make up the gaseous atmosphere. Satellite instruments may broaden our understanding of the enigmatic primary radiation, which enters the atmosphere with energies of many billions of electron volts. That energy release is many thousands of times greater than the nuclear-fission process of an atomic explosion. One day, perhaps, we may be able to harness such power. The satellite may show us the way.

Unprecedented study of solar phenomena—the character, in-

tensity, and time relation of the emission of ultra-violet, corpuscular, and X-ray radiation from the sun—will be possible. Correlating such data with presently observable solar processes such as sunspot severity, aurora, geomagnetic and ionospheric disturbances, radio noise bursts, corona activity, and solar flares, will provide us with a deeper understanding of our globe.

The satellite will furnish data concerning the average number of meteoric dust particles, probably less than one-tenth of a millimetre in diameter, which collide with a body in space. Willy Ley has pointed out that visual brightness of the satellite surface might provide a definite clue to the unknown density of cosmic dust. We can provide the satellite with a polished surface. The high reflection of the artificial moon should be gradually dimmed by constant impact with billions of tiny cosmic particles. Visual brightness, as a result, diminishes noticeably to tracking instruments. As the reflecting powers of the satellite lessen, the temperature will increase correspondingly because more solar radiation, hitherto reflected back into space when the surface was shiny, will be absorbed by the metal surface. From the reduction of this visual brightness and the temperature increase telemetered to earth, the probable number of cosmic particles could be established within quite reasonable limits. Laboratory calculations indicate that, in space, sunlit aluminium receiving the unfiltered blast of solar ultra-violet radiation will reach a temperature of 802° Fahrenheit. This is well above its softening point. Exposing various metal sheets to maximum solar radiation, with heat levels telemetered to recording instruments on the earth, may determine the metals best suited for space-ship construction.

A television transmitter may be included in the satellite. When this proposal was first advanced, over-zealous satellite enthusiasts predicted it would provide a constant watch on aggressive moves of

an enemy nation. Of course, the transmitter in the satellite might fail either before or after the missile was established in its orbit, and failure could come about for any one of a few hundred reasons. There are other, and more serious, difficulties to be overcome before the unmanned satellite will serve a useful purpose as a military watchdog. Among them is the questionable seeing value of a television transmitter in seeking out points of potential military danger. In the face of the many obstacles, it seems hardly likely that the first satellite will serve this purpose. A television transmitter would, however, prove a scientific boon to many scientists. Mounting the transmitter so that it encompasses earth's star in its view will permit un-excelled views of the sun. Kinescopes of these scenes and of the earth will prove invaluable in broadening our understanding of the solar system and this planet.

Meteorological science is sure to benefit through transmission of earth views from the satellite. The movement of cloud and air masses will allow a better understanding of the characteristics of the upper atmosphere, enabling us to chart with accuracy newly created typhoons, hurricanes, tornadoes, and other destructive weather forces.

The motion of the satellite will be so planned that it will cross the invisible line of the equator at an angle of 45°, orbiting the missile over the most populous parts of the world. Combining the satellite's orbit with the earth's rotational movement produces a giant "weaving" pattern, since a satellite at 346 miles in height would complete a revolution once every 96 minutes.

The satellite orbit has been described as beyond the atmosphere and in empty space; technically speaking, however, at 300 miles above the earth, space isn't quite so "empty." For all practical purposes, or the maximum height at which there is a sufficient density

of gases to affect the movement of rockets like the V-2, the atmosphere may be said to "end" 20 miles above the planet.

Among scientists, however, there is little agreement as to what constitutes atmosphere. The preceding description applies to only one of many phases of upper-atmosphere exploration, and the validity of a statement that the atmosphere ends at 20 miles, or 200 miles, or 5,000 miles, is not acceptable to many scientists. One figure does find acceptance—an outside limit of 60,000 miles. This may vary by several thousands of miles; there is no clearly defined atmospheric limit or a "beginning" of space.

Sixty miles above the earth, atmospheric characteristics as we know them are no longer recognizable. From this point on to "empty" space, there exists a weird maelstrom of fierce electrical activity, extending from the 60-mile stratosphere level to the limits of the ionosphere at a little more than 200 miles. Here is that region of which science knows so little, the exosphere. Its final limits, where outer space begins, may be anywhere from an arbitrary 1,500 to 60,000 miles. Our limited knowledge permits no more exact figure than this.

Man will soon witness a new star in the heavens, a satellite gleaming in its rapid flight about the planet with a night-time brilliance no celestial object other than the moon ever attains. Only at dawn and at dusk will this fleeting star shine, moving across the blue-black sky from horizon to horizon in 20 minutes. If, one day, you sight this new light racing about the world, you will see the first successful step in our struggle for the stars.

3

The Weakest Link—Man

It seems that the spaceman of the future must possess superhuman powers in order to survive the multiple dangers of space. An overdose of journalistic misinterpretation leaves the layman with the belief that, to avoid being riddled with meteors, fried with ultra-violet radiation, suffocated, boiled in his own blood, sterilized by cosmic radiation, exploded in instantaneous decompression, driven mad by weightlessness, blinded by unfiltered sunlight, frozen in deep space, seared by the sun's heat blast, and mashed into a pulp from plus-gravity forces, a spaceman will need more lives than a dozen generations of cats.

Those dangers are real enough. Any one or combination of them can descend with fatal suddenness on the crews of future space ships and space satellites. Fortunately, our present knowledge, based on research, will enable us to obviate these dangers. We can protect the crew with every facility at the disposal of science and establish for it an artificial environment which will provide the greatest protection against the dangers of space travel. This need for protective caution, however, will have one unfortunate drawback. It will mean that it will be necessary for space ships to perform at less than their design potential; their maximum performance must not at any time exceed the tolerable limits of the human passengers. The

machine can be no better than the man, and man is not strong enough to allow us to send space ships off the earth at the maximum accelerations we can already squeeze out of rocket motors.

Yet, with all his limitations, man is a surprisingly tough creature. It is a never-ceasing wonder to physiologists that the frail mixture of bone and tissue animated by supersensitive nerve networks which make up the human being can withstand as much punishment as that to which it is frequently subjected. We are constantly surprised by stories of physical endurance beyond credence. Combat troops have continued to fight in battle even after the loss of arms or legs; some men have refused to surrender even with half their blood gone, with perhaps a hundred pieces of steel and shrapnel embedded in their bodies, and with limbs hanging by shredded muscles. Such occurrences seem almost to take on the fantasy of fiction. Because of physical and mental conditioning, some men, of course, can withstand physical pain better than others. There are men who with no more than discomfort experience physical sensations which would make quivering wrecks out of others. It is the result of environment, adaptability, and conditioning, rather than a matter of courage.

A knowledge of the fine points of human conditioning and adaptability is of the utmost importance to the physiologists who will select the crew members for the first space ships. The selection will be on the basis of exhaustive physical, mental, emotional, educational, and psychological examinations, all carefully controlled to weed out those men who, for any reason, might prove a hindrance to the success of the first venture into space. These physiologists are well informed as to the limitations of their working subjects. The human body, although we would like to know more than we do about it, has been subjected to painstaking scrutiny for centuries. Science has

applied every technique at its disposal in searching for greater knowledge of man's body and brain.

Man exists under a specified set of environmental circumstances which have, over the ages, shaped him into his present form. He consumes a bewildering variety of foodstuffs; the adaptability of certain groups enables them to exist on foods which would kill or render seriously ill others less accustomed to those substances. Through various of nature's trial-and-error experiments, man has built up a biological resistance to many forms of bacteria and germs which at one time or another have decimated whole populations. Where nature creates temperature extremes, man has proved capable of adapting himself to those extremes. We exist under temperature conditions with an absolute survival range of some 280° Fahrenheit; people of the Near East survive through heat of 180°, while the Eskimo, who would surely succumb to such blistering radiation, thrives in an environment of cold, ice, snow, and barrenness. Although men are continually exposed to cosmic radiation, the race continues, not only to survive, but to increase. Despite many unfavourable factors, man is constantly extending his individual longevity.

All things considered, however, man can survive only if certain basic necessities in median temperature, food and water supply, tolerable radiation, and breathable atmosphere are available.

Despite this basic law of survival, man constantly subjects himself to conditions of great heat, extreme cold, "alien" foodstuffs, unfamiliar diseases, lack of atmosphere, poisons, and variations of gravity which should prove invariably fatal. The paradox is that even under artificially induced conditions which would seem designed to maim and kill, man survives and, indeed, thrives lustily. The intrinsic factor which makes possible this seeming paradox is that the

human being, through the manipulations of science, can protect himself with artificial means of survival which enable him to triumph over the surrounding environment. The ratio of success or failure to survive any normally lethal environment is subject entirely to the adequacy and reliability of man's protective facilities.

Men have flown at speeds of 1,300 miles per hour in rocket aircraft; protected by the aeroplane's steel and glass body, they do so without experiencing ill effects. The human body moving through the atmosphere at such speeds without protection would be quickly torn to shreds. At 15 miles above the earth more than 90 per cent of the breathable atmosphere disappears, yet men fly at such heights. Hundreds of feet below the ocean surface the pressure is sufficient to mash a man's body beyond recognition, yet, protected by steel shells, men survive such descents as a matter of routine.

The list of similar circumstances is long and detailed. Every condition under which man survives, when nature normally demands death of the venturesome, is of paramount interest to the space doctor. He already knows a great deal about the strains which extraterrestrial flight will impose on the human body. He must ensure that the limitations of the passenger are not exceeded by the performance of the space vehicle, lest such performance transcend the maximum of resistance, and death or disability be the result.

Plus and Zero Gravity

Least understood of all the new sensations which men in space will experience is that resulting from gravity, or, to be more precise, the *lack* of gravity.

Weightlessness—zero gravity, as it is often called—is inevitable in space travel. A man in space, either orbiting about the earth in a

satellite or within a space ship on his way to Mars, is weightless. Unless he orients himself with his eyes, looking at the familiar confines of a space-ship cabin or any other reference point, his understanding of "up" and "down" becomes meaningless. There are no verticals or horizontals, as we interpret such terms on earth. On this planet, "up" is towards the sky, above our heads. This must be so, since any object which does not rest upon the ground, and has no other support, falls "down."

What is gravity? There are a number of definitions; some scientists call it a constant force, others term it a mutual attraction between two bodies, and still other scientists describe it as a force of acceleration.

A common belief is that the weight of an object is a constant, that it is always the same under any conditions. If a man weighs 150 pounds when standing on a scale, then no matter what that man does, or where he goes, his own body weight is still the same. This is not at all true. Ever since man began to fly, he has experienced a variation in weight. It seemed, under certain flight conditions, that he weighed either more or less than when he was standing on the ground. This is due to the fact that the forces acting on his body in flight were far different from what they were on the ground.

Years ago it became evident that we must revise our concept of weight. A man standing still on a scale may register a weight of 150 pounds. If he jumps upwards, pushing against the scales, the weight registered by the scale suddenly and briefly shows a temporary increase to 230 pounds. If weight were a constant, this could not occur. Something happens, when the man jumps, to cause a momentary change in his weight as registered on the scale. That something is the force of inertia.

Reviewing one of the laws established by Sir Isaac Newton

enables us better to understand this force. Newton stated that every action has an opposite and equal reaction: Every application of force exerted in one direction exerts a similar force in an opposite direction. According to this law, a force acting on a body and accelerating it has a counterpart which is commonly referred to as the force of inertia.

Newton's law allows us to understand why the man's weight suddenly increases when he jumps up from the scale. When the man is at rest, his body weight remains constant. To move off the scale, however, certain force is required. That force comes from the muscles in the man's legs; he first crouches down slightly, then leaps upward. At that moment his legs exert a downward force. Following Newton's law, we realize that the downward push of the man's legs, temporarily registered on the scale as 80 pounds, is great enough to raise the man's body a certain distance off the scale. To establish the weight of a body or an object, then, the scale and the object resting on the scale must be at rest. Alternatively, one may say that neither scale nor object must be accelerated. Since our interest in weight, or gravity, is based on its relationship to space travel, we sometimes use a different description of the forces of inertia, calling them g-forces.

Let us return to the scale and the man, replacing him with a slab of iron of the same weight. By some magic we suddenly transfer the scale and iron far out into space, where no gravitational field exists. Scale and iron bar are then weightless. In space we accelerate the scale and its iron bar. That acceleration exerts a force of inertia equal to the force of gravity exerted on the scale and iron bar when both were standing still on the surface of the earth. When we read the needle on the scale, it will show a "weight" of 150 pounds for the iron bar. This actually is not weight, but a force of inertia equal to 150 pounds.

We cannot distinguish between an inertia force of 150 pounds and a weight of 150 pounds unless we know whether the scale and iron bar are resting on the earth or are being accelerated through space. If we were to enclose scale, iron bar, and a man in a totally enclosed box, for example, he would not be able to tell whether he were at rest on the earth or moving through space at a velocity of 1 g. Both scale indications could accurately be called weight, or both could be called force of inertia. The difference is that we are led to believe that a body actually has two distinct types of masses. One of these is the gravitational mass, a characteristic displayed as the attraction between two bodies. This is the more familiar quantity to us.

The earth is an object. So is the scale, and its iron bar. (We can assume for purposes of explanation that the scale and bar are one.) The earth, of course, is the more massive of the two objects. The mutual attraction between the two bodies, which we call gravity, constantly pulls the scale and iron bar towards the centre of the earth. Resting on the surface of the earth, their weight, or g-force, is measured as 150 pounds for the iron bar, plus the weight of the scale.

The other kind of mass is called inert mass. This is a quantity which manifests itself as a force of inertia during acceleration. The scale and iron bar moving in space is an example of this type of mass.

One could say, then, that gravity is correctly expressed as acceleration. In fact, an Einsteinian explanation would suggest that a body at rest on the surface of the earth is not really at rest at all, but is being continually accelerated upwards.

For purposes of travel in space, however, we do insist upon a differentiation between gravitational mass and inert mass. Since this differentiation appears unnecessary, as no experiment and no means

exist to separate one from the other, why do we make a discrimination which cannot be proved?

The difference is this: We call the weight of an object, obtained on the surface of the earth under unaccelerated conditions and when the object is at rest, "normal weight." That object, however, may not always be at rest. It is then in a state of acceleration. This means that a force of inertia is added to, or is subtracted from, the normal weight, resulting in an amount of weight which can be anything from zero or weightlessness to many times the normal weight.

The weight of a body, then, is the result of its state of acceleration. Everyone has at one time or another been subjected to increased or decreased weight because his body was in a state of acceleration, as when making a sharp turn in an automobile. The body has a tendency to continue in the direction in which a vehicle was moving before making a turn. A more dramatic instance of a body in a state of acceleration occurs when one rides in a fast elevator. If one moves upwards, it seems that he suddenly becomes much heavier and his knees tend to buckle. As upward acceleration occurs, body weight increases. Contrariwise, when the elevator drops one experiences a giddy, falling sensation. This is also a product of a state of acceleration, but in this case body weight decreases.

There exists a certain unfortunate confusion as to the proper definition of *weight.* The Department of Space Medicine, United States Air Force, has for years considered the question. What is probably the best answer is that given by Dr. Fritz Haber, of the Department of Space Medicine: "*The weight of a body is equal to the force of its support, and is independent of the force gravity.*" Dr. Haber states that weightlessness is a condition which can be established anywhere, and that this condition is independent of the existence of a gravitational field. He gives this example:

"Take a bottle partly filled with water, seal it, shake and mix the contents; the air and water inside the bottle will separate very quickly, just as soon as we stop shaking the bottle, due to the difference in weight of water and air. In a state of weightlessness, however, this separation does not take place because water and air do not have a different weight; that is, they both have no weight. We can now render the bottle weightless by depriving it of its support—that is, by allowing it to fall. During the fall we can then see that the water and air do not separate, but stay mixed. This is proof that the state of weightlessness is possible even in a gravitational field. It is also proof that the weight is equal to the supporting force."

All these definitions of gravity, weight, inertia, and g-forces have been necessary in order to provide a basis for understanding what happens to a man when he goes through the complicated process of blasting off this planet in a space ship. From a condition of normal weight, he will be subjected to g-forces which will increase a normal body weight of 200 pounds to as much as 2,400 pounds! He will be subjected to the indescribable sensation of instantaneously being transferred from such crushing forces to a condition of weightlessness.

The Limiting Factor

The conclusions so far reached as to the impending conquest of space rest equally on fact and fiction. A book on space travel would have little indeed to say if the contents were not a mixture of existing knowledge and scientific speculation.

With science to aid us, we can reasonably estimate what will happen to man under the harrowing conditions to be met in space. It must be made clear, however, that even with all the knowledge at

our disposal, we are confronted with the unknown. We cannot make any bland assumption that man will adapt quickly, or with little difficulty, to this alien environment. Whether or not man can tolerate for extended periods of time a wide departure from his accustomed surroundings is a scientific "guesstimate." Men have endured gruelling conditions on the earth, it is true, but even the worst on this planet pales to insignificance beside the extremes of space. When we know more of human capacities, when we have carried out further tests with fuels, metals, and instruments, and examined even more carefully the enigmatic problems of space travel, it is quite possible that we will be forced to revise considerably our present concepts.

Our knowledge of the human being leaves the space scientist unsatisfied. It is the cardinal rule of the men evolving space travel that the physiological problem must be solved before manned space ships are built. There is little purpose in fabricating a multimillion-dollar machine if the weak link that is an inadequate crew is to wreck the entire venture. The United States government in 1949 established the Department of Space Medicine at Randolph Air Force Base, Texas. It was created as part of the organization of Rand Corporation, sponsor of the Earth Satellite Vehicle Programme, under the general co-ordination of the Committee on Guided Missiles, Joint Research, and Development Board. The Department of Space Medicine itself is an extension of the United States Air Force's School of Aviation Medicine and was formed with the express purpose of scientific investigation into the medical effects of weightlessness, acceleration, radiation, and other factors on the crews which will eventually conquer space.

The Department employs a bewildering variety of apparatus to carry out its experimental work. One of the most important of these is the United States Navy's newest centrifuge. This largest of all

centrifuges is part of the Aviation Medical Acceleration Laboratory at the Naval Aid Development Center, Johnsville, Pennsylvania. The centrifuge itself is within a large research building. At the centre is a power turn-table, where the centrifuge, a 50-foot-long bridge-like tubular structure, is anchored. At the end of the bridge-like arm rests a sealed, elaborately equipped steel gondola. Strapped into a cockpit seat within the gondola, the guinea-pig pilot is subjected to a variety of forces and conditions duplicating the worst conditions of aeroplane flight and many of the forces which will be encountered within a space ship.

Sealed within the gondola, rotated about on a vertical axis, the pilot-occupant can be exposed to crushing accelerations many times that of normal gravity. Within seven seconds of starting, the centrifuge can whirl at 174 miles per hour, or 48 revolutions per minute. Capable of exerting an acceleration force up to 40 gs, under maximum operation the centrifuge could raise the weight of a 200-pound man in the gondola to as much as four tons!

High-altitude conditions similar to those up to 60,000 feet are simulated. Pressure drops at the whirl of a knob; within seconds temperature soars from a comfortable 44° to a sweating 110° Fahrenheit. Motion picture cameras record in detail the occupant's every action under conditions of great stress. X-ray cameras enable scientists to study internal organs. The human guinea pig bristles with wires connected to his body, transmitting vital physiological processes to banks of instruments.

The centrifuge is indispensable for studies of reaction under severe acceleration and deceleration. We have seen how weight is varied by changes of acceleration. During take-off a space ship exerts severe plus-gravity force—a force of inertia many times that of normal body weight—on its human passengers. Although too much

ILLUSTRATIONS

1 At 3.14 p.m. on February 24, 1949, this two-stage Bumper rocket, a V-2 with a smaller WAC-Corporal in its nose, attained a speed of 5,100 miles an hour and an altitude of 252 miles. For the first time in history a man-made object had entered empty space.

2 Backbone of the American postwar rocket and upper atmosphere research effort was the wartime German V-2 rocket, of which 100 were shipped to the United States after the war and 68 were fired in varied experimental shots.

3 Fifty-seven miles above the earth, cameras in an Aerobee rocket show a 1,400-mile strip extending from upper Wyoming into Mexico.

4 Theo Poppel, a German scientist and a member of the ground equipment crew, is shown adjusting one of the jet vanes that control the V-2's attitude in flight.

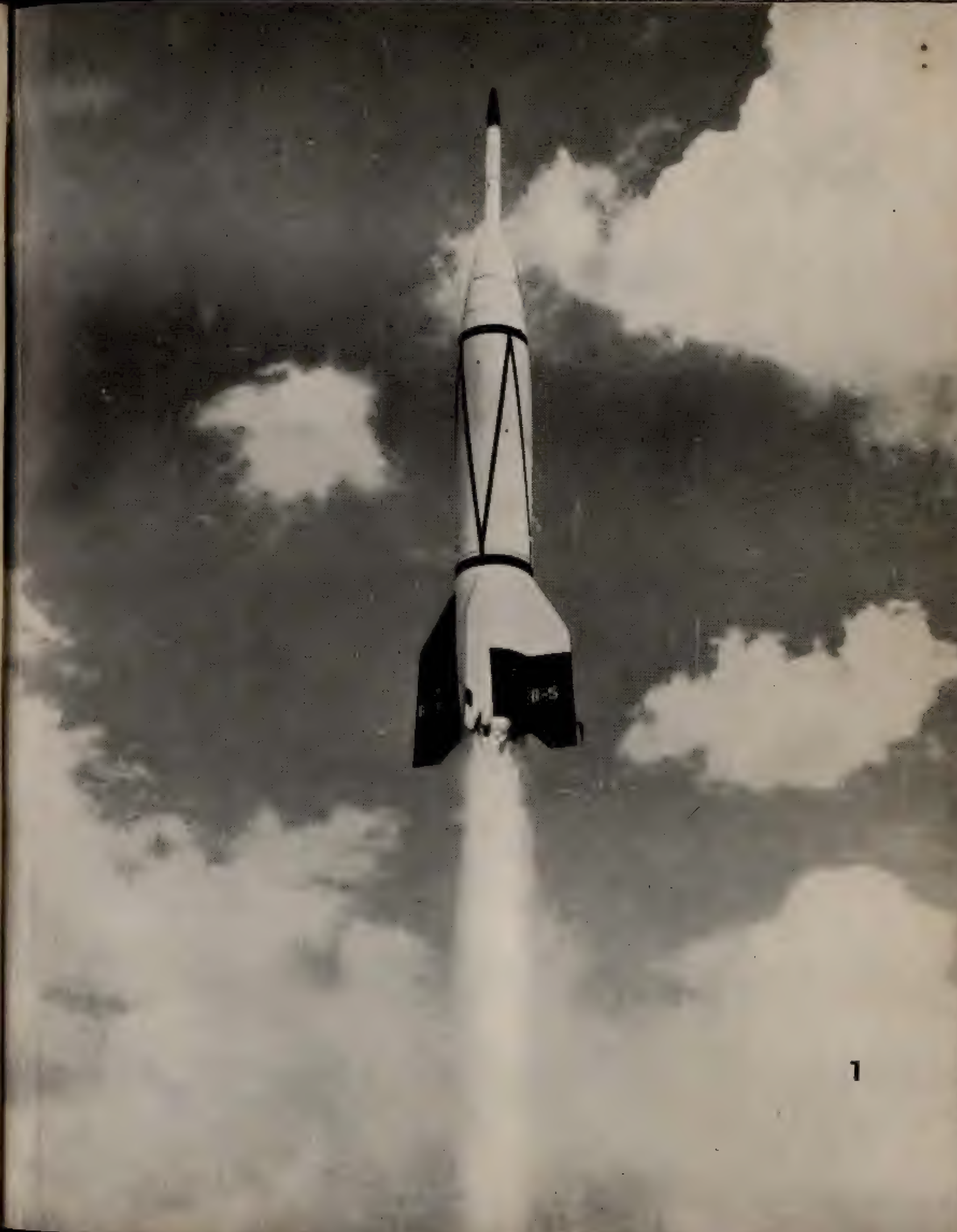
5 One of the rarest rocket photographs ever made. A modified V-2 with sharply swept-back wings standing on the launching-pad before its firing in Germany. The Germans planned to construct a great number of rockets known as the A-9, which were winged V-2s with a maximum range of approximately 300 miles. The rocket shown is actually an A-4b, a modified V-2.

6 Best of the American-designed and -constructed rockets has been the Glenn L. Martin Company's Viking, built for naval research activities. The slim missile, with equal the length of the V-2 rocket, incorporated many design innovations and improvements over the wartime German V-2.

7 The night before a V-2 launching was usually filled with long hours of hard, last-minute servicing of the rocket's intricate parts and its precision scientific instruments.

8 Under the brilliant floodlights of the gantry crane, the Viking motor is serviced during the night prior to launching. Following this work, the Viking will be bolted securely to the launching-stand, the gantry crane rolled back, and the Viking motor tested at full power.

Captions continued on page 53



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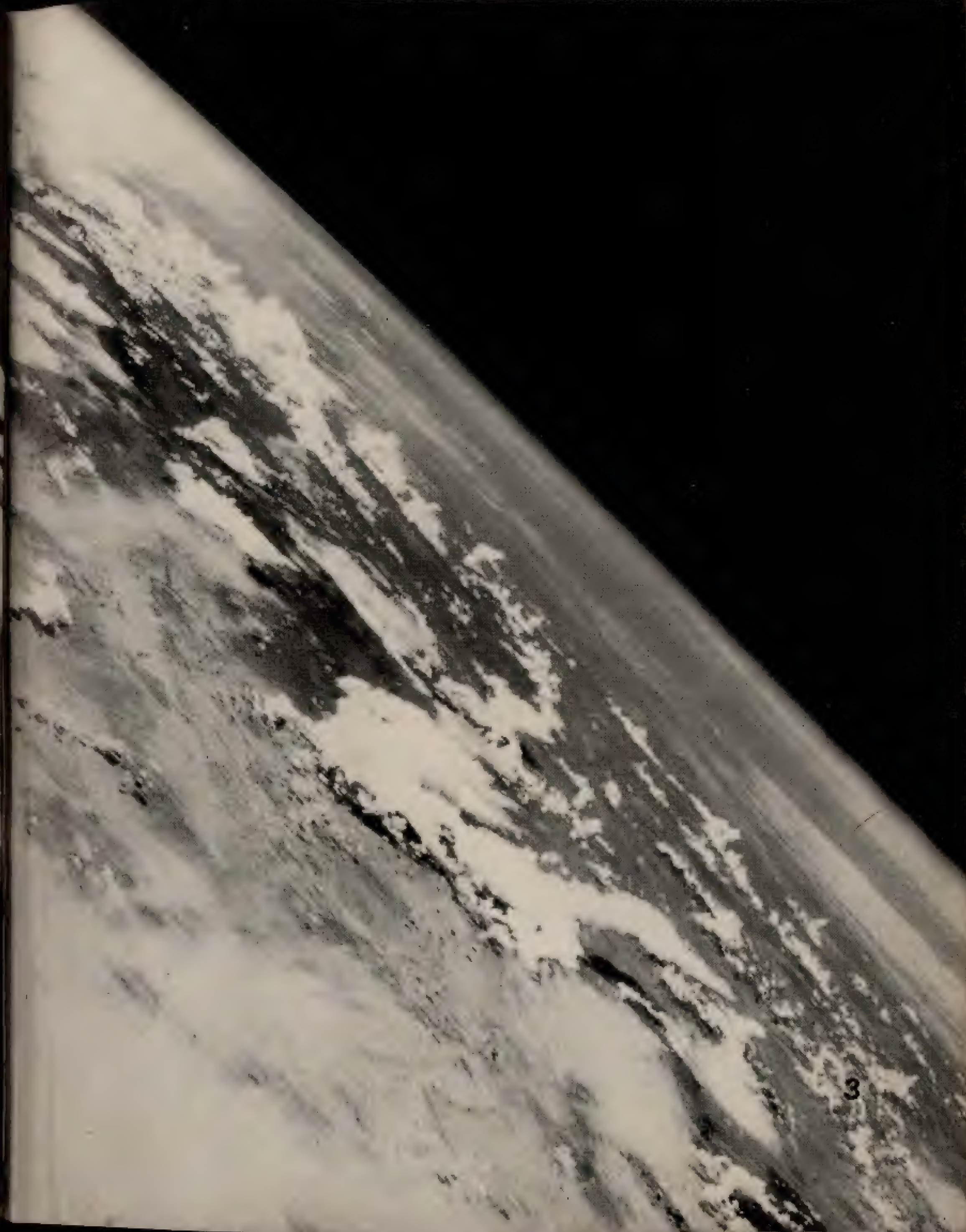

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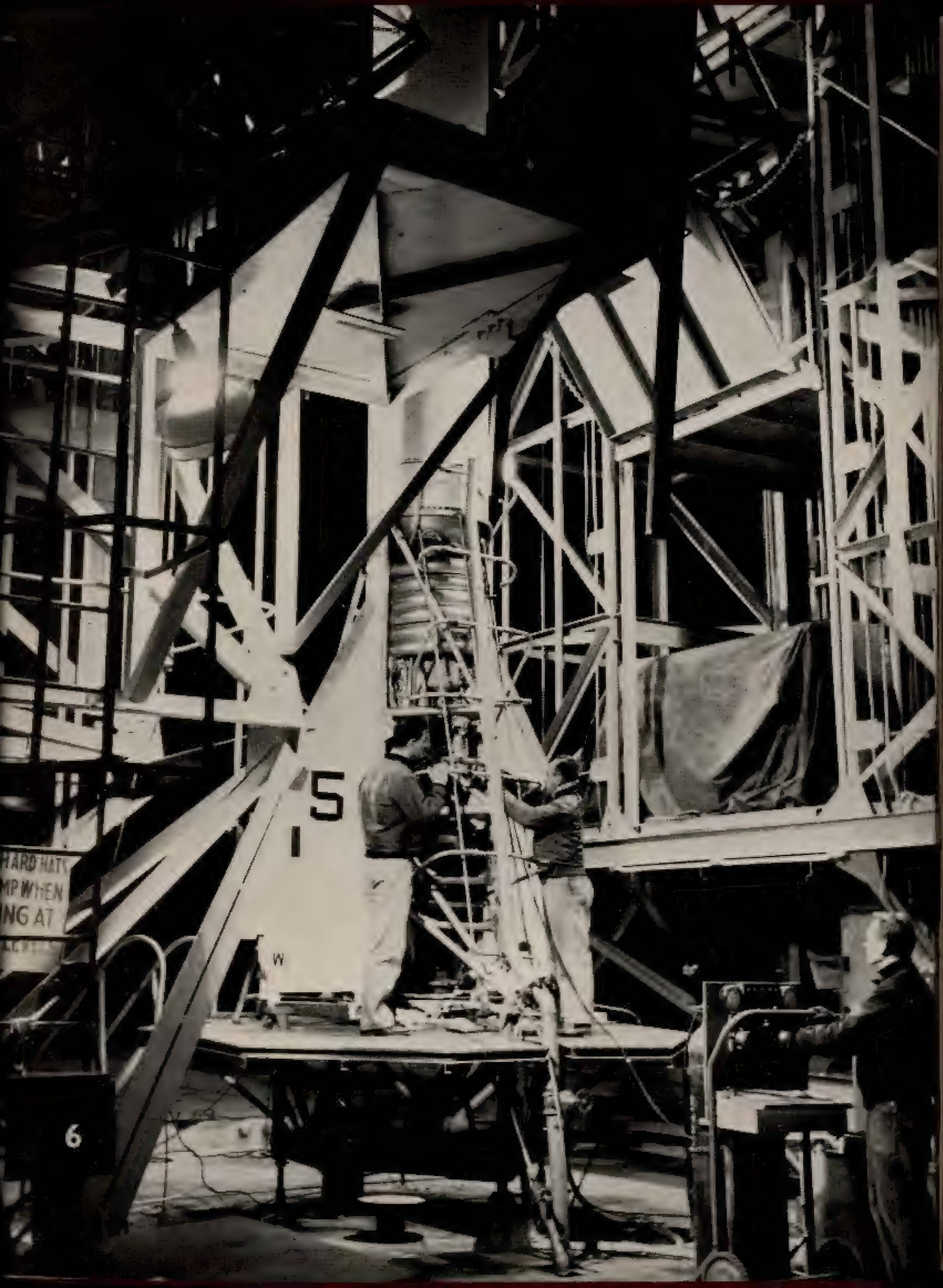
HARD HATS

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11

ILLUSTRATIONS

The record-breaking Viking No. 5 leaving the launching-stand, on its way to establish a new altitude record of 107·3 miles for an American-built single-stage rocket. 9

A completely redesigned and re-engineered Viking, No. 9, thunders off its launching-pad at White Sands, on December 15, 1952. 10

One of the postwar Army series of guided missiles, the long and slender Corporal E, is shown leaving the launching platform with an unusually bright exhaust flame. 11

Used extensively by the Air Force to study human reactions to high g-forces, this centrifuge at the Aero-Medical Laboratory at Wright Field has demonstrated that a well-trained human can withstand a force of 12 gs for several minutes without physical harm. 12

World's largest known centrifuge is this giant human centrifuge chamber of the Aviation Medical Acceleration Laboratory at the Naval Air Department Center, Pennsylvania. 13

A full view of the Navy's revolutionary pressure suit shows the pilot in a mock-up of an aeroplane cockpit seat. 14

The delta-wing design is the most efficient wing plan for high-speed aircraft, allowing controlled supersonic flight while providing great wing area for lift at extreme altitude. 15

The scarred, pitted, and blasted surface of the moon's southern portion, as seen during the last quarter. 16

acceleration cannot be permitted, since it would crush the body into a jellied pulp, nevertheless a high degree of acceleration is necessary to permit the space ship, consuming fuel in prodigious quantities, to break free of the ground and get into space in the shortest possible time. The necessary compromise between the two demands lies in an acceleration factor lower than the maximum possible performance of the space ship, yet high enough so that inferior performance will not consume all the fuel before the ship is high enough and moving fast enough to escape from the earth. Within these restrictions, can we build a space ship which will break the earth's gravitational pull without inflicting physical damage to its crew? The answer, from years of experiments with various "gravity" devices such as the centrifuge, is an unreserved "yes."

Visualize a space ship during take-off. The giant craft is about to start on its journey; the rocket motors thunder at maximum power. These motors develop a certain thrust, measured in tons, which is slightly greater than the weight of the entire space ship. While not much greater, it is sufficient to lift the space ship off the ground slowly, very slowly, in the first few seconds of flight.

The thrust of the rocket motors is a constant: they will generate, let us say, 2,000 tons of thrust at the moment of firing; a minute later they will still be generating 2,000 tons of thrust. The total mass of the space ship, however, is steadily decreasing, since fuel is rapidly being consumed and discharged during the operational period of the rocket engines. Thus we have a constant propulsive force acting on a space ship of steadily decreasing mass. Because of this action the space ship continues to gain velocity at a constantly growing acceleration. The result is an ever-increasing force of inertia acting on the space ship and the crew. This steady increase of weight continues for the entire propulsion period. After the space

ship has attained the desired speed and height, the rocket motors are abruptly cut off. Suddenly the thrust and the support have disappeared. Since no support is the equivalent of no weight, the space ship and everything within it become weightless as soon as the rocket thrust is stopped. The velocity, the earth's gravitational field, or the trajectory of the space ship does not influence the condition of weightlessness.

Just how much acceleration—an increase in body weight—can the human body withstand? Physical conditioning has much to do with the answer. The position of the body during the acceleration period also plays an important role in determining maximum permissible acceleration. Aeroplane pilots are familiar with plus-gravity forces, since in certain manœuvres a force of inertia increases body weight considerably. Pilots refer to this increase as so many gs, or multiples of gravity. In modern high-speed jets, for example, a pilot can fly at 600 miles per hour in level flight. By making a sharp turn with the aeroplane, he subjects himself to a rapid and material increase in the force of inertia. For a period of several seconds his body weight is greatly increased, and the several gs hold him to his cockpit seat with invisible fingers of steel.

The more popular conception of g-forces in aircraft is allied with the picture of a long dive at high speed and a sharp pull-out from that dive. In this manœuvre a pilot can withstand 3 gs—a threefold increase in weight—without difficulty. At 4 gs, the neck muscles can no longer support the head. The strongest man finds it almost impossible to raise his arm, and encounters some trouble in breathing. At 5 and 6 gs, breathing is still more difficult due to lessened ability to raise and lower the lungs. Five to ten seconds of a sustained 6-g force render a man unconscious.

Since the g-forces are experienced in an aeroplane, all this takes

place with the pilot in a normal, seated position. During the crucial moments of pulling the machine out of its dive, the pilot's body weight is increased from an average of 180 pounds to a severe 1,080 pounds at 6 gs. This added pressure causes the lower blood vessels to become distended. Blood rushes downward from the head in what is called the "fluid shift"; deprived of vital blood and oxygen, the brain and eye retinas fail. The man "blacks out." Maintenance of this force with the pilot in his seated position for more than 30 seconds will almost certainly result in permanent physical damage, and probably death.

By whirling a pilot about in the centrifuge, medical scientists determine how many gs he can withstand and still be capable of emergency-control action. When a space ship takes off, it is unnecessary for the human pilot to control the vehicle on its upward, sloping trajectory. In fact, it is imperative that he refrain from doing so. The mechanics of the take-off trajectory are so precise that the human pilot cannot hope to compete with the exacting manœuvres of electronic computers and relay timers which fire the rocket motors and make all the necessary changes in climb and power. The pilot and crew are passengers.

If something goes wrong—if an electrical connection fails, if the pressurized system breaks down, or if a fuel line bursts in a sheet of flame—the pilot may be forced to take emergency control of his ship in the critical climbing phase. Therein lies another factor limiting permissible g-forces: The control system must be so designed that the pilot can perform emergency manœuvres when necessary. Nevertheless, the demand for power, because of excessive fuel consumption, is so great that g-forces, while within permissible limits, are so great that they may prevent the pilot from raising his arms! This emergency is met by providing push-button controls

right at the pilot's fingertips, to be utilized only in extreme emergency.

Six gs are about the maximum a man can withstand in a normal, seated position for ten seconds before unconsciousness overtakes him. There is a way to increase the maximum number of gs a man can stand without physical harm, and also to increase the time element when those g-forces are applied. The human body in a prone position—the crew flat on their backs on special cushion supports—can tolerate for two to three minutes an elevenfold increase in weight. In a supine position this weight increase can be 14 times normal body weight for the same period of time. These values are not estimates, but were obtained in tests with a constant acceleration.

Constant acceleration demands a note of explanation. The take-off of a space ship does not suddenly impose greater weight on the crew but results, rather, in a steady increase in weight. It reaches its peak at the end of the propulsion period. Doctors are concerned with this factor for more than mere physical reasons. To tolerate a severe increase in weight is always uncomfortable; to know that it will become continually worse during the thundering rocket climb can unhinge man's mind.

Unconsciousness can occur even in a supine position. Assuming a steady acceleration, two to three minutes of 14 gs is supportable. Maintaining this acceleration for more than three minutes, or increasing the acceleration to more than 14 gs, means that the critical point of resistance has been reached. Blackout occurs when the weight of the blood is increased to such an extent that the heart can no longer keep it circulating through the arteries and veins. The brain and eye retinas, likewise deprived of vital blood and oxygen, fail.

Men spun about in the Air Force centrifuge at Wright-Patterson Air Force Base, Ohio, taking chest-to-back accelerations up to 10 gs, were still able to move their arms and legs. Other men have actually taken 17 gs in a centrifuge and remained conscious all through this strenuous application of force. The ability of certain men to withstand 17 gs, while others black out and have no control of their senses at less than 10 gs, emphasizes the greater physical resistance and psychological adaptability of some men over others. Colonel Don Flickinger of the United States Air Force states that, of every 1,000 choice spaceman applicants, only five—for physical, educational, and psychological reasons—will be judged suitable.

Rocket engineers assume that, because of the limitations of chemical fuels, any space ship capable of breaking free of the earth's gravitational pull must be a multistage vehicle. We are already acquainted with the take-off manœuvre of the unmanned satellite to its orbit several hundred miles above the earth. A multistage, manned space ship appears to be the only feasible means of transporting a crew and substantial payload of cargo to this height. To understand the acceleration forces acting on the crew during a typical three-stage space-ship climb, we must consider a vehicle designed to reach an altitude of between 1,000 and 1,100 miles. The crew at take-off is in supine position, resting on special acceleration couches which enable the men to absorb high g-forces by gradually giving way beneath the men's bodies as the peak g-load is reached.

After 80 seconds of powered flight, the first stage has about exhausted its fuel. The crew is now under a peak force of 9 gs. Breathing is difficult, due to the tremendous weight of the chest, which must be moved for the purpose of respiration. This crew, however, is hand-picked. Every member is able to withstand heavy g-forces better than the average man. He has had experience under

high gs, having been whirled in centrifuges on many occasions. His body, aided by a fine state of physical conditioning, receives further assistance through controlled breathing, a process evolved by the medical scientists who run the big centrifuges. Suddenly the third-stage motors are throttled back to the barest cruising power; this enables the second-stage motors, when fired, to pull away from the speeding third stage. At the moment the first-stage motors are throttled back, the crew feel a brief relaxation of the crushing weight which has pressed them back into their contour couches. Their faces, lips, and skin, stretched downwards into a grotesque mask, revert to more familiar features. The second stage roars into action. G-forces steadily increase until, two minutes later, a peak of 8 gs is reached. Motors are throttled back, and the third-stage rockets burst into flame. Ninety seconds later a 3-g peak is reached. When the third stage reaches desired velocity and height, power stops.

There is no longer any support. The ship and crew are completely weightless. A stunned exhaustion is their first reaction. Suddenly they are falling, tumbling endlessly over and over into a bottomless abyss. If these men had not been carefully screened and trained and subjected to brief periods of weightlessness before this flight, they would be in a frenzied state of terror.

Zero Gravity

Terror, the first reaction to weightlessness, is natural and instinctive. It stems from childhood; one of the more forceful nightmares most young children experience is that of hurtling downward into a void. When the crew of the space ship were first subjected to zero gravity, much of the battle to overcome this instinctive fear had already

been fought for them. They had, for one example, been carefully selected from thousands of young aspirants, and their reactions to a weightless condition were such as to promise the greatest resistance. Some men have a natural ability to withstand weightlessness; others can never hope to overcome the basic fear of falling. Fear of height is common to humans; some people need only to stand on the edge of a high cliff, or look out of the window of a tall building, to court vertigo. They become dizzy, lose all sense of balance, and if not held may tumble to certain death. Fear is associated with the terror of falling. In space, if a man has not been trained to overcome this innate emotional instinct, every sense in his mind and body will shriek for support, anything to halt the terrible and endless plummeting.

The space doctors, therefore, select only those men who can easily withstand long drops through the air. An aeroplane pilot may, and usually does, enjoy what he terms flying for fun. It is not uncommon for pilots to wring their planes out in aerobatics which would leave the majority of us gasping, quivering wrecks. In an aeroplane performing wild gyrations, our sense of balance suffers a nearly total eclipse. Inertia mashes a man down into his seat until he gasps for breath; suddenly the aeroplane hurtles skyward and the sensation of weight almost disappears. The horizon spins dizzily and ceases to exist, while lights flash before his eyes. A few minutes of this and the untrained passenger realizes only that he is finally being dragged out of the cockpit eons later, weak and nauseated and dizzy, and swearing never to try the experience again. Nevertheless, some men thoroughly enjoy this.

What is weightlessness like? Since not all of us have had the experience of being whirled about in an aeroplane, we may use an ordinary elevator as an analogy. Anyone who has experienced a

quick drop in a fast elevator has had a brief sensation of weightlessness. The peculiar stomach-lifting sensation, which may induce nausea, results from relaxation of ligaments which support the normal weight of the intestines. This sensation is momentary. In space it will be sustained inescapably.

We can make some good estimates of the other sensations arising from zero-gravity conditions and gauge their effect on the human system. It is important, however, that we make one admission in our discussion of these sensations: We are completely in the dark as to what a *prolonged* state of weightlessness will do to the human body. Experiments so far made with weightlessness seem to rule out severe disturbances of circulation. Many of the body functions are independent of gravity and require only atmospheric pressure. For example, gravity is not required to aid the heart in pumping blood through the system. A contrary argument states that, if the blood suddenly becomes weightless, the heart, accustomed to pumping specific quantities and weight of blood, must suddenly race out of control. Current space-medicine theory answers with an emphatic "no."

To test this theory it would be necessary to place a man in a situation where he is weightless. Unfortunately the current state of rocket technology does not permit us to do this safely. Scientists have, however, sent small mammals to as great a height as 80 miles to test their physiological reactions under zero-gravity conditions. In tests conducted in Aerobee rockets with two mice and two monkeys at Holloman Air Force Base, New Mexico, all four animals were recovered in good health after the shots. One of the monkeys is so healthy and has grown to such size since his epochal journey above the earth that he is now too large to fit into a rocket compartment. From these experiments and others with V-2 rockets at White Sands,

Air Force medical scientists draw the conclusion that it is possible for a mammal to function normally at zero gravity. The monkeys and mice experienced no unusual effects from the shots, although they were subjected to a brief initial acceleration of about 15 gs lasting less than one second, and a longer force of 4 gs lasting for 45 seconds. For the shot the monkeys were anaesthetized to prevent them disturbing the instruments necessary to record their physiological reactions.

During the periods of zero gravity, a mouse floating freely inside a smooth-walled drum appeared completely to have lost his senses of direction and orientation and was unable to direct his movements normally. The other mouse, inside a drum with a small shelf, clung to this shelf while weightless, orientated himself, commanded his body at will, and did not float in space. These reactions, plus those of human occupants in an aircraft designed for special performance, indicate that a man properly secured can function normally during periods of zero gravity and carry out any necessary control operations.

Valuable as these tests are, at best they provide only a clue to prolonged reactions to weightlessness. It appears that much of the falling sensation experienced under conditions of zero gravity can be eliminated by actual contact with a non-moving object. A crew member strapped into his seat would have some sensation of being held down; indoctrinated by psychological training and capable of appraising his environment intelligently, he might well learn to ignore to a very great extent, perhaps completely, the less desirable sensations of zero gravity. Conceivably, this conditioning might fail during periods of sleep, when the mind is no longer alert enough to ward off the deep-rooted sensations of falling. Man, fortunately, has good adaptive abilities and there is every indication that he will be able

to overcome even the more serious difficulties. This will not, however, be a sudden achievement and may require very extensive training.

Orientation in zero gravity depends almost entirely on the visual recognition of immediate surroundings. Unless the eyes are open, a man cannot possibly hope to recognize the deck or the right or left bulkheads of the space ship. The sense of balance depends upon normal function of the tiny utricular labyrinths of the ears. When weightless, these do not function normally and the senses cannot give the brain a true report of balance. A man reclining on a bunk, unless held down, would be unable to judge whether his legs were resting on the bunk or floating freely several inches above. Trying to sit down might prove a rather awkward experience at first; when one intended to squat down, one's knees might rise. With one's eyes shut, it might be impossible to tell if one's arm was raised or lowered. The terminals of so-called kinesthetic perception, the nerve endings and internal organs, respond partly to muscle tension and partly to gravity. Under normal body weight on the earth, they register the position of all body parts. In space, however, these kinesthetic terminals no longer obtain from a familiar body weight the information usually transmitted to the brain, and orientation disappears. Aeroplane pilots flying blind have experienced similar reactions. Enclosed within a cockpit, a pilot cannot tell whether he is inverted. The normal senses fail completely; instruments must tell him whether he is heading in the right direction, is flying right side up, is diving or climbing, or is banked at some dangerous angle.

Spacemen must develop a completely new sense of balance. This may not be nearly so difficult as it seems. Many of us have so thoroughly acquired unusual balance senses that they become a

normal part of everyday life. One who attempts to ride a bicycle acquires cuts, bruises, and a conviction that it is impossible. A few weeks later he rides his bicycle serenely; the process of balance is by now instinctive. Our greatest aid will be experience. Spacemen may find it difficult to evolve a sense of balance without the familiar aid of gravity. To move about a space-ship cabin, for example, a man cannot simply walk, since walking as we normally know this act is impossible in space. He will either pull himself, hand over hand, about the cabin by grasping fixed objects, or he will "swim" through the air. A slight shove will easily propel a man through the cabin. The technique will be somewhat complicated, since a man may rebound if he cannot grasp some object when he arrives at his destination. Experience will allow proper "aiming" of the body. Unless the spaceman shoves off from a wall at the proper tangent, he will float off at an angle different from that intended. Thrashing his arms and legs about will be of little help.

Even involuntary muscle twitches in the space-ship cabin will unbalance a man to some extent, but experience will compensate for such involuntary movements. A man strapped into his seat or bunk cannot float about. Magnetic garments may be one solution, since they will cling to the metallic fixtures and space-ship walls. This may be of questionable value, however, since it will involve the necessity of peeling oneself like a sheet of flypaper from a steel wall.

When performing certain work, such as that done by a navigator, a man will find it necessary to anchor himself to his seat or place of work. If not, the slight reaction of a pencil when writing would be sufficient to send him drifting through the air. Magnetic-soled shoes offer one solution to getting about a space ship. Standing still, however, the magnetic shoes would help to anchor the man at only one

point. With his feet clamped to the deck, he would sway about like a tree in a strong wind.

Walking with magnetic shoes in zero gravity poses other problems. One must overcome the magnetism holding one's boot to the deck by muscle strength before the boot will lift clear. The sensation of lifting the foot probably resembles that of walking in sticky mud. The moment the boot breaks free of the deck by the exertion of sufficient force to break the magnetic contact, boot and foot will sail "upwards."

Many of the normal body functions do not depend upon weight. One can eat or drink regardless of body position. Eating when upside down is uncomfortable and perhaps a bit gagging, but no less possible than when one is seated at the dinner table.

What to eat, and how to eat it in space, is a more complicated matter. Consider liquid foods. They are absolutely necessary, yet we cannot drink as we normally do on earth. The liquid is weightless and therefore will not pour from a pitcher or container. Since there is no gravity to "pull it down" when it normally leaves the pitcher, it would scatter throughout the cabin in thousands of small globules. Liquids will be kept in containers and consumed through straws, or more probably in plastic holders with nippled openings. Placing the nipple in the mouth and squeezing—gently, lest the liquid shoot into the mouth under strong pressure—will enable one to ingest liquids.

Sandwiches, fruits, bulk vegetables, and meats are the most desirable foods. Meat must be cooked in totally enclosed electronic cookers; if not enclosed, small bits of hot fat will shoot across the space-ship cabin. It is not difficult to determine what types of food are unsuitable for a space ship. The attempt to eat fragmentary

foods, such as peas or beans, with a fork or spoon would send them scattering in all directions. Similar foodstuffs, obviously, cannot be brought along.

Knives and forks will perform the same functions as on earth; knives can still cut and forks can jab and secure a slice of meat. The spoon will undoubtedly give way to a new type of eating utensil, probably a clamp or flexible metal pincers. Magnets will secure eating utensils in place, to keep them from drifting about.

Food in bulk is absolutely necessary for nourishment, and magic pills can never be a substitute for this. The body demands a minimum of two pounds of carbohydrates a day; this can be derived only from food eaten in bulk. The physiological make-up of the internal organs requires bulk food to fill the large space in the intestinal tract; unless pills equal in bulk to normal food consumption are eaten (which would kill a man), that man will continue hungry and the body will suffer from a drastic alteration of its normal processes. Space-satellite crews will undoubtedly add to their normal diet some form of multi-vitamin pills. Satellite crews on extended tours of duty will probably receive ultra-violet-ray exposure.

Evacuation of body waste is another physiological process independent of gravity. Atmospheric pressure and muscular movement control such action, but disposal of waste will demand special equipment. Chemical toilets appear indispensable, and it will be necessary to equip them with special suction fans to collect solid waste matter. Disposition of liquid waste may be achieved by equipment similar to that employed in long-range fighter aeroplanes; a relief tube is used when the pilot is forced to remain in a seated position for long periods of time. In the space ship, a combination of a relief tube and suction will be required.

Spacemen won't breathe the same kind of air they did on earth.

Pure oxygen cannot, of course, be used. The air, basically of an oxygen (40 per cent) and helium (60 per cent) mixture, will in all probability contain a mixture of quantities of dust, iodine, ions, and other substances found in our normal air on earth. It may prove necessary to provide this kind of aerosol complex. We know that the oxygen-helium mixture is more than satisfactory for short periods of time, but we do not yet know what effect extended respiration without the familiar components of the aerosol complex will have on men.

Nitrogen, comprising 78 per cent of our atmosphere on the planet surface, will not be carried into space within air tanks because of the possibility of explosive decompression, a killer more to be feared than g-forces. Simply stated, explosive decompression is a sudden drastic loss of air pressure. The average man goes through his entire life without ever experiencing this uncomfortable and sometimes fatal accident. Years ago a lesser degree of explosive decompression was responsible for the crippling and death of many deep-sea divers. Working under conditions of crushing water pressure, the diver was protected by a "cushion" of air in his diving-suit under high pressure. Surfacing demanded a gradual ascent to obviate the dangers of rapid decompression or reversion to normal atmosphere. When inevitable accidents occurred, or when emergency ascents were necessary, divers shot up from deep water and inevitably suffered attack that became known as the "bends." Normally, a certain amount of nitrogen is inhaled into the body during breathing; this dissolves in the blood-stream and body tissues in amounts which are not harmful. Under conditions of rapid decompression, however, nitrogen bubbles are created in quantity in the blood-stream, with resulting physiological reactions which are sometimes fatal.

Space doctors hope to eliminate the possibility of such a calamity in a space ship or space satellite. Under conditions of a "blow-out" in space, the atmosphere within the ship actually blows out through the ruptured wall into the surrounding vacuum with explosive violence. Explosive decompression can very quickly kill a crew. One way to minimize the dangers of explosive decompression is to eliminate the nitrogen in the air. Although helium also dissolves in the body, it is only one-fifth as soluble as the fatal nitrogen. Rapid decompression in an oxygen-helium atmosphere forms some bubbles in the blood-stream, but far short of the number which would normally cripple or kill a man. Deep-sea divers, lowered to great depths after breathing oxygen-helium before and during their descent, were able to survive with little harm rapid decompression which would have killed them had they been breathing oxygen-nitrogen.

Another method of warding off the dangers of rapid decompression in the space ship is to live in an atmospheric pressure of only eight pounds per square inch as compared to the earth surface average of 14·7 pounds per square inch. This enables a man to become better accustomed to abrupt changes in atmospheric pressure. Since the oxygen content in the space ship is 40 instead of the normal 21 per cent, a man obtains his necessary oxygen requirements despite a reduction in pressure of nearly 50 per cent. However rapid a decompression the deep-sea diver experiences, he always returns to a normal atmospheric pressure of 14·7 pounds per square inch. When explosive decompression occurs in space, however, the result is vacuum, and the consequences are infinitely worse.

Visualize the cabin of a space ship. A weak joint in the side of the vehicle, further weakened by the strain of acceleration and pressure from within, suddenly ruptures. The air explodes outward into space. Under such conditions a man experiences a violent evacuation of air from the lungs, caused by the disappearance of the exploding atmosphere of the space ship into space. This rush of air resembles an explosion in the lungs, as the air rushes with great force out of the nose and mouth, tearing tissues and blowing them outward. Oxygen in the blood-stream also rushes out of the body. The men are agonizingly racked by these terrible, strange forces. The body will continue to live only for seconds on the oxygen stored in the blood and tissues from previous breathing. Unless additional oxygen under pressure is administered immediately, death is inevitable.

Unhappily, explosive decompression poses additional physiological hazards. U.S.A.F. scientists have placed beakers of warm water in high-altitude decompression chambers, then rapidly lowered the air pressure. When the pressure level fell below that experienced at 63,000 feet, the water in the beaker bubbled furiously. At a simulated pressure of 90,000 feet the water literally exploded out of the beaker in a burst of fine spray and water droplets.

The contents of the vessel reacted as though they had been subjected to a heat of several thousand degrees. The temperature did not actually increase; on the contrary, it had dropped to bitter cold. The reduced pressure simply released the gases in the water. Blood is more than nine-tenths water. A man subjected to decompression would first find his blood racing madly, actually boiling, and then exploding forcibly. Bloody froth would instantly fill the lungs, with fatal consequences. Space doctors are haunted by the dangers of explosive decompression, particularly because any satellite orbiting about the earth is constantly bombarded by meteor particles. Most of these are no larger than fine grains of sand; occasionally, however, they are the size of a pea or small rock, sufficiently large to blast a large hole in the outer skin of the satellite.

Spacemen must run the gauntlet of exposure to another extra-terrestrial hazard: cosmic radiation from outer space. Cosmic radiation has come in for increasingly detailed study by thousands of scientists in recent years. The V-2, Aerobee, and other rockets fired to extreme altitudes all contributed much to our knowledge of cosmic radiation. Millions of dollars have been expended by the military services and research organizations in attempts to crack the mystery of cosmic radiation and to discover its source and the nature of its energy. Our knowledge of cosmic rays is unfortunately meagre. We must learn much more, for locked within the secret of cosmic radiation is power of a scale which renders comparatively puny the violence even of nuclear fission. We know nothing of its source. The many theories on cosmic rays are unable to provide conclusive evidence as to the point of origin of this ultra-powerful energy.

Scientists believe that cosmic rays are the atomic nuclei of helium, hydrogen, and other elements. The instruments borne to extreme altitude by rockets and balloons offer strong evidence to support this theory. Unfortunately, present balloons and rockets cannot meet the performance demands of cosmic-ray scientists. A rocket which can place instruments in space, beyond the tangible atmosphere, for long periods of time, is indispensable to further study. Only then can we hope to determine whether or not cosmic radiation is unaltered in its passage through the tenuous particles whirling about the earth at great distances. Scientists are not certain that the radiation recorded by the highest rockets is identical to that which will be experienced in outer space.

Our meagre knowledge allows us to classify cosmic rays as "primary" and "secondary" radiation. Primary cosmic rays moving at a velocity approximately that of light collide in infinite numbers

with atoms in the upper atmosphere. This produces a spreading series of chain-reaction energy showers, known as secondary cosmic rays. The protective lower-atmosphere blanket renders secondary radiation harmless on the surface of the earth. This secondary radiation is almost entirely absorbed by other atmospheric atoms before reaching the earth's surface. At 60,000 feet secondary cosmic radiation becomes a physiological hazard. United States research and military aircraft, already flying above this height, bring pilots into the region of danger. The Douglas D-558-II Skyrocket, for example, has flown above 79,000 feet; the Bell X-1 has made repeated flights to 60,000 feet, and current military jet aircraft, including those of the United States, England, and Russia, are flying approximately at the same height. Aviation physicians do not consider that the problems of exposure to cosmic radiation are something to be solved in the future. They demand attention now.

Space ships leaving the earth pass through the region of secondary radiation quickly. At the orbiting height of a satellite, 1,075 miles, they court only the danger from primary cosmic radiation. Space doctors wish to learn what the cumulative effects of exposure to these primary rays will do to a man. It is currently believed that the light nuclei among primary cosmic rays are not dangerous, but that continued exposure to the atomic cores of oxygen, carbon, and nitrogen might have a deleterious effect on spacemen. These nuclei penetrate several inches into living tissues, leaving behind them a path of dead cells. It is to be doubted that the effect resembles the illness resulting from exposure to the radiations emanating from an atomic bomb explosion.

For several years it was felt the danger of such exposure, even for short periods of time, would be so serious as to make space travel impossible. Scientists now tell us that danger from the single

high-energy particles in space is actually less than from the scattered radiations of the atomic explosion. In their opinion cosmic rays will not even produce noticeable genetic effects, even under conditions of long exposure. Scepticism on this score, created by the heralded dangers of explosive and residual radiation from atomic bombs, is dissipated by a realization of the true facts. People may remain in an area which has been heavily contaminated by an atomic explosion all their lives, without suffering from radiation sickness; such immunity under prolonged exposure, however, is possible *only when the radiation level is below a certain intensity.*

The time element is all-important when considering exposure to radiation. For example, were a person to receive within the space of a few minutes a dosage of 600 roentgens (a roentgen is a measurement of radiation), he would almost certainly die within a short time. However, were this same individual to remain in a radioactive area in which he would gradually absorb the same dosage over the space of a lifetime, he would suffer no serious physical effects. For this reason, while space physicians recognize primary cosmic radiation as a possible physiological hazard, they consider it a remote danger and believe that a healthy human being can tolerate such exposure.

The Spacesuit

Rocket engineers usually assume that development of chemical fuels and the space ship are the major factors hindering space travel. Actually one of the major stumbling-blocks is the spacesuit.

In February of 1953 the United States Navy announced the development of a revolutionary high-altitude pressure suit for pilots, successfully tested at altitudes of 70,000 feet. At this height a man

would die within a few seconds if not protected by either a pressurized cabin or the new suit. According to *Collier's*, the suit was developed by the Navy with space problems in mind, and was so constructed as to permit complete freedom of movement. It was also claimed to be usable on the moon when that future need arises.

The suit was developed under the direction of Captain James Sullivan of the Navy Bureau of Aeronautics, at a cost of nearly a quarter of a million dollars. Many details of the revolutionary garment have been withheld for security reasons. Manufactured by the B. F. Goodrich Company, it employs fabricating techniques of the David Clark Company, and its hardware is supplied by the Firewel Company and the Bendix Aviation Corporation. The suit will be produced in three permanent sizes at a mass-production cost of perhaps two thousand dollars per unit. The wearer is afforded complete mobility through semi-rigid accordion pleats which allow movement of such important body joints as the knees, elbows, and shoulders. Ingenious wrist joints permit rotation of the hands. The headpiece is permanently attached at the shoulders. Although the head is totally enclosed within the transparent helmet, an oxygen mask fastened securely to the face provides breathable air for the occupant. While it is contended that the suit allows the occupant full mobility, it is not stated whether that mobility is limited to the confines of an aircraft cockpit, which seems most likely, or applies to movement on the ground. To claim that this suit will protect a man on the moon, because of vacuum conditions, is to assert a half-truth. A spacesuit must be far more than merely a high-altitude pressure suit. The Navy suit, undoubtedly capable of meeting every requirement for extreme-altitude aircraft, certainly is no substitute for a spacesuit, although this appears to be a commendable step towards achieving the ideal.

Time, in its issue of December 8, 1952, quotes a U.S.A.F. source to the effect that a full-pressure suit will keep a man alive in a complete vacuum for about ten minutes, however difficult it will be to breathe under such conditions. The Air Force was referring to its own high-altitude pressurized suit, which is standard equipment for aircraft flying above 40,000 feet, but which does not totally enclose the wearer. There may be some significance in the fact that the Air Force experimented with a totally enclosed pressurized suit for some time before development of the Navy equipment, but abandoned that unit as premature.

Dr. Fritz Haber of the Department of Space Medicine has expressed the opinion that it may be necessary to abandon the entire spacesuit concept. If men wish to float round their space ships, according to Dr. Haber, it will be necessary for them to do their work inside rigid cylinders, attending to mechanical details with remote-control devices. However controversial the question may be, it is encouraging to realize that the Navy high-altitude pressurized suit, designed to keep a man alive in a vacuum, will serve as the basis for developing an actual spacesuit, capable of protecting a man against all the dangers of a new environment.

It must totally enclose the wearer and must within itself provide all the necessities for survival without dependence on any outside source. It must be entirely self-sufficient with regard to air. This implies not only a supply of breathable pressurized air, sufficient to last several hours, but adequate provision for the elimination of the carbon dioxide of respiration, and for the removal of excess water vapour, chiefly the product of exhalation. The suit must be a complete and effective air-conditioning unit. It must be provided with temperature control capable of meeting the extremes encountered in space. The problem of stabilizing internal suit temperature, regardless of surrounding temperatures, may find its solution in a double wall separated by a cellular material which offers high resistance to the passage of heat.

Adequate boot insulation is required. This is a matter of furnishing protection against conduction effects: the transfer of heat from the boot to the outside surface, or vice versa. This insulation of the entire spacesuit and boots must be effective on the moon, for example, in a temperature range of from 248° Fahrenheit to −238° Fahrenheit. When man explores the other planets, such as Mercury, suit insulation must compensate for an additional several hundred degrees of temperature rise.

The glass visor permitting visibility must protect the wearer against the searing brilliance of the sun in space, and screen out dangerous ultra-violet radiation, fierce enough to turn glass black. Since no atmospheric blanket is present in space to burn up grain meteor particles, the suit must have a separated space layer acting as a meteor shield. Protection against larger meteoric particles is impossible, but the mathematical odds against being struck by such a particle make the risk a remote one.

Whatever safeguards may be devised, accidents in space are inevitable. Most predictions of space travel, for some obscure reason, disregard the fatality and accident factor which will certainly accompany our struggle to conquer space. It would be impossible to list here all the sources of danger beyond those few already described, just as it is not practicable to predict all dangerous situations.

For example, a man forced to abandon his space ship several hundred or several thousand miles above the earth, even if alive and well within a spacesuit, could survive only briefly. Falling to earth from this height through the outer belt of the atmosphere, he would

be subjected to a deceleration of 300 gs upon striking the top of the atmosphere! The shock of such deceleration is more than sufficient to kill him. Even if he could miraculously avoid this fate, his falling speed would be sufficient, due to friction with the atmosphere, to burn him to ashes.

4

The first Space Ships

Most rocket engineers believe that the first space ships to carry men from the earth will be multistage affairs which jettison empty fuel tanks and motor sections in their upward fight against gravity. Engineers stress the fact that before the large space ships, designed to construct satellites and travel to other celestial bodies, are built, "Model T" vehicles must ascend actually to test in space many scientific and physiological theories.

This need for basic research in advance of actual launchings of manned rocket vehicles has long been recognized. In 1946 two British designers, R. A. Smith and H. E. Ross, submitted to England's Ministry of Supply detailed plans for a man-carrying research rocket. The project was advanced as the most direct means of obtaining information on a rocket flight's effects on a human being under certain conditions. Specifically, scientists would be provided with more extensive experimental data on acceleration, deceleration, and weightlessness through the test shot than could be obtained by any other means. This experience would result in manual control of a rocket during the period of powered ascent, and the feasibility of returning a sealed, pressurized cabin with a human occupant might be demonstrated. The interpretation of high-altitude data, instrumentally obtained, could be checked against the direct

observation of the crew member. Experiments could be made with pulse transmission of voice communications from a height of as much as 225 miles, through the ionized layers existing below this level; and the effects of fading, distortion, and directional aberration under various atmospheric conditions could be checked.

The British proposal envisioned construction of a rocket vehicle with less than twice the total weight of the V-2. At take-off it would weigh 20·9 tons, of which 17·2 tons would be the alcohol and liquid oxygen fuels. The sealed cabin and pilot, with accessory equipment, would constitute a weight of 1·29 tons.

A variation of the British proposal by Smith and Ross is found in the illustration section. Slightly larger than the British proposal, the vehicle pictured provides for the accommodation of two men rather than one. In this design the usual tail fins are conspicuously absent. The designers reasoned that the efflux vanes, in the path of the fiery exhaust, are adequate to maintain a vertical path during ascent. Since the vehicle would be beyond the limit of the atmosphere, where its flight could be affected by the surrounding air, at the conclusion of the firing period, the fins would incur only additional weight and drag. Fins are required for the V-2 to achieve "arrow stability" properly to strike its target, but the manned vehicle is in no need of this assistance, since the pilot can direct its flight.

No high g-forces were planned for the passenger. The initial motor thrust would be 30 tons; after a flight period of about 110 seconds, the pilot would be exposed to a constant acceleration of 3 gs. This was regarded as the safety limit within which the passenger could actively handle the controls; when the 3-g factor was reached, automatic controls would throttle back the motor to maintain this degree of acceleration. Separation of the sealed gondola from the rocket hull was contemplated when a velocity of 4,700 miles per

hour was attained. At this precise moment the passenger would manipulate the control to separate the gondola from the hull, driving the sealed cabin away from the rocket section. This control would also operate a time mechanism for the release of the large hull parachutes, intended to return to earth undamaged the tank and motor section.

Motor thrust would constitute a total time of 148 seconds, after which the sealed cabin would continue upwards under its own momentum for an additional 228 seconds. Six minutes and 16 seconds after take-off, the cabin would be at the peak of its trajectory above the earth. During the cabin's upward coasting period and during its descent, the designers intended that the cabin should be rotated to produce some semblance of artificial gravity. As it fell back towards the earth, a large parachute would open to lower the cabin and its single passenger safely to the ground.

Since the proposal was advanced nine years ago, it has become apparent that unsolved problems of rocket control during ascent, and difficulties in safely returning a large object to earth from great heights with parachutes, render the possibility of success less than the designers anticipated. During the upward coasting period, despite the spinning motion of the cabin, there is no provision to prevent the cabin from tumbling end over end in space, as rockets do when ascending vertically, hurtling nose over tail during their unpowered climb above the tangible atmosphere. Certainly the possibility of success in lowering the cabin with its passenger is not very great, as experiments with nose sections of guided missiles have shown. Above 50 miles the parachute is ineffectual as a braking device; sudden return to the atmosphere would subject the passenger to severe deceleration.

Unfortunately, current data on human resistance to g-forces

were not available when Messrs. Ross and Smith conceived their man-carrying rocket. Three gs is rather conservative, as the preceding chapter illustrated. Probably this figure could have been doubled without loss of control efficiency on the part of the occupant. The British designers, perhaps because of lack of knowledge, not available for several years after their design was made public, do not provide for the single crew member to be in supine position during acceleration.

The return of manned vehicles from great heights above the earth will be accomplished with winged space ships performing much like supersonic aircraft. The British proposal for returning the human in his sealed cabin to earth promises very little chance of success. High-altitude rocket experiments indicate that steel-mesh parachutes connected to the cabin by cables, with the parachute area only a fraction of that of the normal nylon parachute, promise greater success than do bulky conventional 'chutes.

While heavy equipment, including howitzers and jeeps, has been dropped from military transports by parachute, a space-ship gondola returning to earth from a height of many miles is hardly comparable to a howitzer dropped from a height of 2,000 feet at a mere 150 miles per hour.

The steel-mesh 'chute, although more practical for deceleration and safe descent through the atmosphere, drops so rapidly that ground impact would be severe enough to smash the capsule and possibly kill the occupants. As is explained in greater detail in Chapter 7, solid-fuel rockets at the base of the capsule, activated by a proximity fuse for a firing time of several seconds, could provide the final deceleration necessary to ensure a safe drop.

It is obvious that the establishment of stations in space must antedate the actual exploration of the moon. Space satellites require

multistage vehicles to transport men and equipment to the desired orbit and velocity above the earth; these space ships will represent, over a period of years, hundreds of thousands of tons of supplies and propellants, and billions of dollars. For the initial plunge into space, then, we may employ a scaled-down, multistage space ship accommodating two or three men. It will orbit about the earth at a height of several hundred miles, with a velocity of more than 16,000 miles per hour, for a period of several days. A venture of this nature answers the demands and remains within the capabilities of the rocket industry. The cost would be considerable, but not so great as to be objectionable. It would allow, in the immediate future, verification of theoretical space-travel data and permit a host of scientific experiments.

It is the aviation industry's practice to construct and fly scaled-down models of very large aircraft, before the final aircraft is constructed, to test in flight the aerodynamic characteristics and performance of the design. Designers scrutinize the behaviour of the flying scale model, either piloted or remotely controlled by radio, and make necessary modifications in the final aeroplane at minimum expense and trouble. Britain's outsize Vulcan delta-wing bomber is a good example. Piloted fighter-size models of this aircraft flew for years before the Vulcan ever took wing. The Consolidated-Vultee aircraft company in the United States has long test-flown scale models of its proposed flying-boat designs, taking the models off and flying them by radio control. The same process probably will be carried out with the first large multistage space ships. With the exception of crew facilities and total operating components, the model space ship will be a smaller replica of the giants to be built later. The first step contains the fuel tanks, accessory power units and equipment, and five rocket motors, of which one is used for altering the

angle of attack during the climb through the atmosphere. When the fuel is exhausted this stage is jettisoned. The second stage also is jettisoned after its fuel has been consumed. The third and final stage, accommodating crew and scientific equipment, is finally established in an orbit several hundred miles above the earth, moving at approximately 16,000 miles per hour. It will remain in this orbit for several days.

Before the entire three-stage ship hurtles into space, extensive glide and power tests will be carried out with the third stage. Just as modified bombers today carry to a height of 35,000 feet rocket-powered supersonic experimental aircraft, a modified bomber will probably carry the third stage seven or eight miles above the earth for drop and glide tests. Released from this height at several hundred miles per hour, the unequipped third stage will be flown many times in this fashion to study flight characteristics. The space pilot will manœuvre his craft as he would a high-speed aeroplane, landing the space ship without power in dead-stick landings.

When these flights have supplied the desired data, the fuel tanks will be filled and the space ship will once again be borne aloft by a bomber to a height of about 40,000 feet. Sealed in the pressurized cabin, the three crew members will wait for their ship to be dropped. Seconds later, plummeting down and forwards in a high-speed glide, the pilot will energize the single powerful rocket motor, pulling the ship into an almost vertical climb. For the next few seconds the space ship will behave like an aeroplane, which for all practical purposes it is. The delta-wing shape will shudder and rumble momentarily as the great power of the rocket motor boosts it past the speed of sound.

Nose pointed straight up, the ship will hurtle into the upper atmosphere at a speed of several thousand miles per hour. Inside,

the three-man crew will be pressed into their acceleration couches under the force of the climb. But only for a little while; soon the pilot throttles back the motor and eases the space ship into a more gradual climb. The motor is silent as the space ship coasts along on its momentum in a giant arc. For several minutes the men will be almost weightless.

Before long the ship strikes the upper atmosphere, heating up as it plummets through the resisting air. Gradually and easily, the pilot returns his craft to earth. When the temperature generated by air friction reaches a dangerous point, the ship will be lifted upwards again, bouncing on the air like a flat stone skipped across a pond. The speed will not be so great as to prevent the space ship from returning to the stratosphere. A long, gliding turn, and the vehicle will be pointed back towards its take-off point, many hundred of miles distant. Several flights of this nature will be followed by powered take-offs from the ground. In all, several hundred test flights, including drops and power take-offs, will be made to prove the ship.

Finally, the great day for the flight into space will arrive. Less than an hour after the five first-stage rocket motors wash the launching-pit with flame, the final stage will be orbiting about the earth, several hundred miles in space, its crew of three experiencing for the first time in history the incredible sensations of sustained weightlessness, seeing in all their glory the heavens, and below them the shimmering, massive globe which is their planet.

For several days these three men will remain in space. An entire world will hang breathlessly on every word radioed back to earth. Reports on their reactions to prolonged weightlessness, and their eating, sleeping, and living habits in space, will be snatched up eagerly by scientists on the ground hundreds of miles below. Thousands

17 The first vehicle to leave the earth and remain in space will most likely be a multistage rocket, with an instrument-packed final stage that will remain for ever in space.

18 The two-stage robot leaving its launching-pad. The great rocket will rise only about 15 feet during the first second after it leaves the ground, then rapidly gain momentum until soon it is roaring upwards at thousands of miles per hour.

19 Three hundred and forty-six miles above the earth, the last stage orbits about the earth at nearly 17,000 miles per hour. Dozens of instruments tightly packed within the nose compartment will send back to earth stations invaluable data on temperature fluctuations, meteor-dust conditions, and other information.

20 One of the major engineering and physiological obstacles to successful travel in the void is development of the spacesuit. The spacesuit must not only provide a proper aerosol complex for its occupant but must provide shielding against extreme heat and cold, loss of heat through conduction, protection against grain meteors, evacuation of exhaled waste gases and other body products, as well as maintenance of internal body pressure.

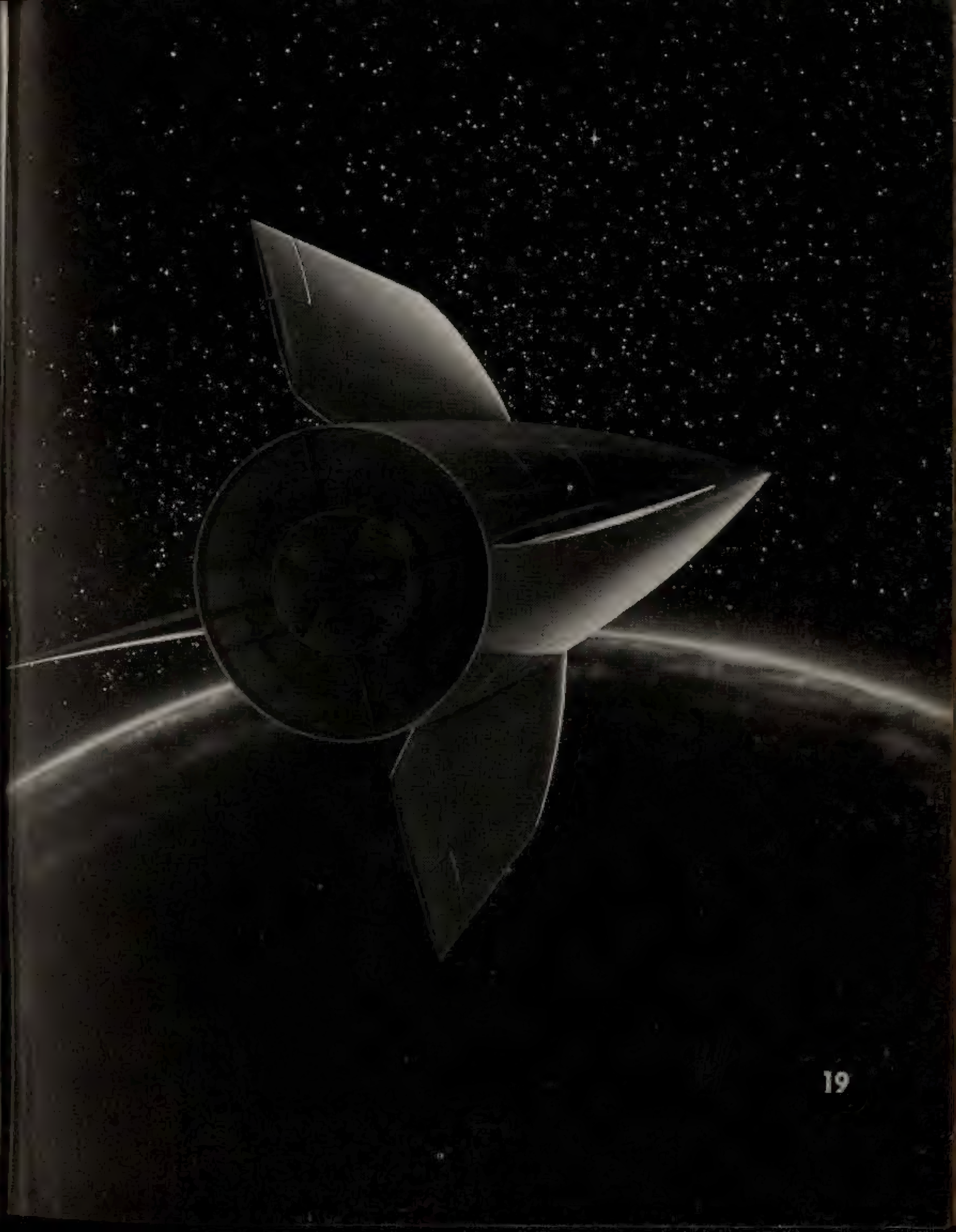
21 Individual orientation in space, under zero gravity conditions, will demand superb physical conditioning and control. Completely weightless, the spaceman will lose all reference as to what constitutes an "up" or "down."

22 In 1946 two British designers, R. A. Smith and H. E. Ross, both of the British Interplanetary Society, prepared detailed plans of a one-man research rocket to test the effects of acceleration, weightlessness, space-ship control, and pressurized-cabin parachute drop. The two-man space ship illustrated is an adaptation of the British proposal.

23 Demanding less of the rocket engineer's ingenuity, the one-way space ship for a moon flight was a rocket proposal highly popular in pre-war times.

24 The atomic-powered space ship on its launching-pad. Final servicing of the mammoth nuclear vehicle is being carried out before the launching.

Captions continued on page 85

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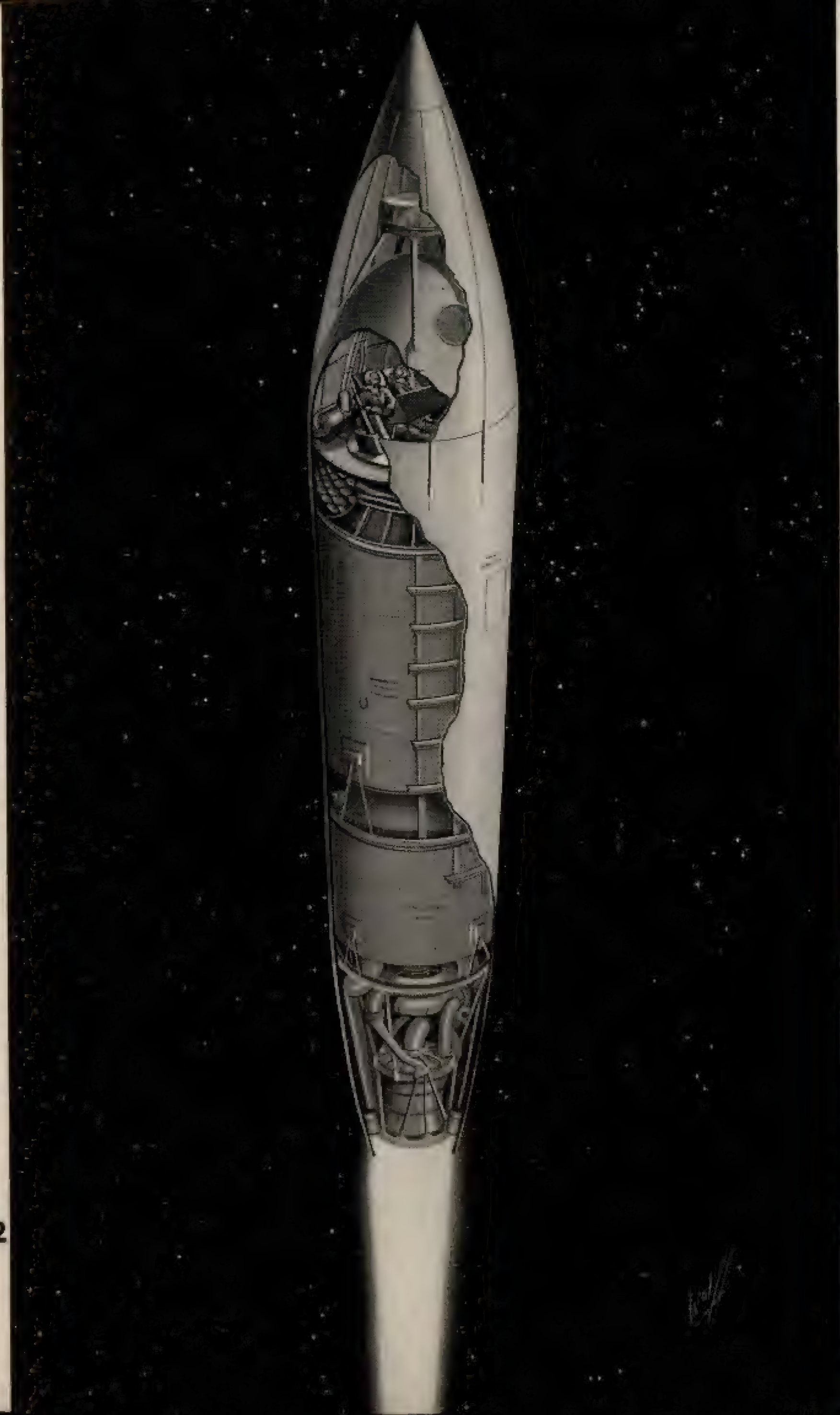
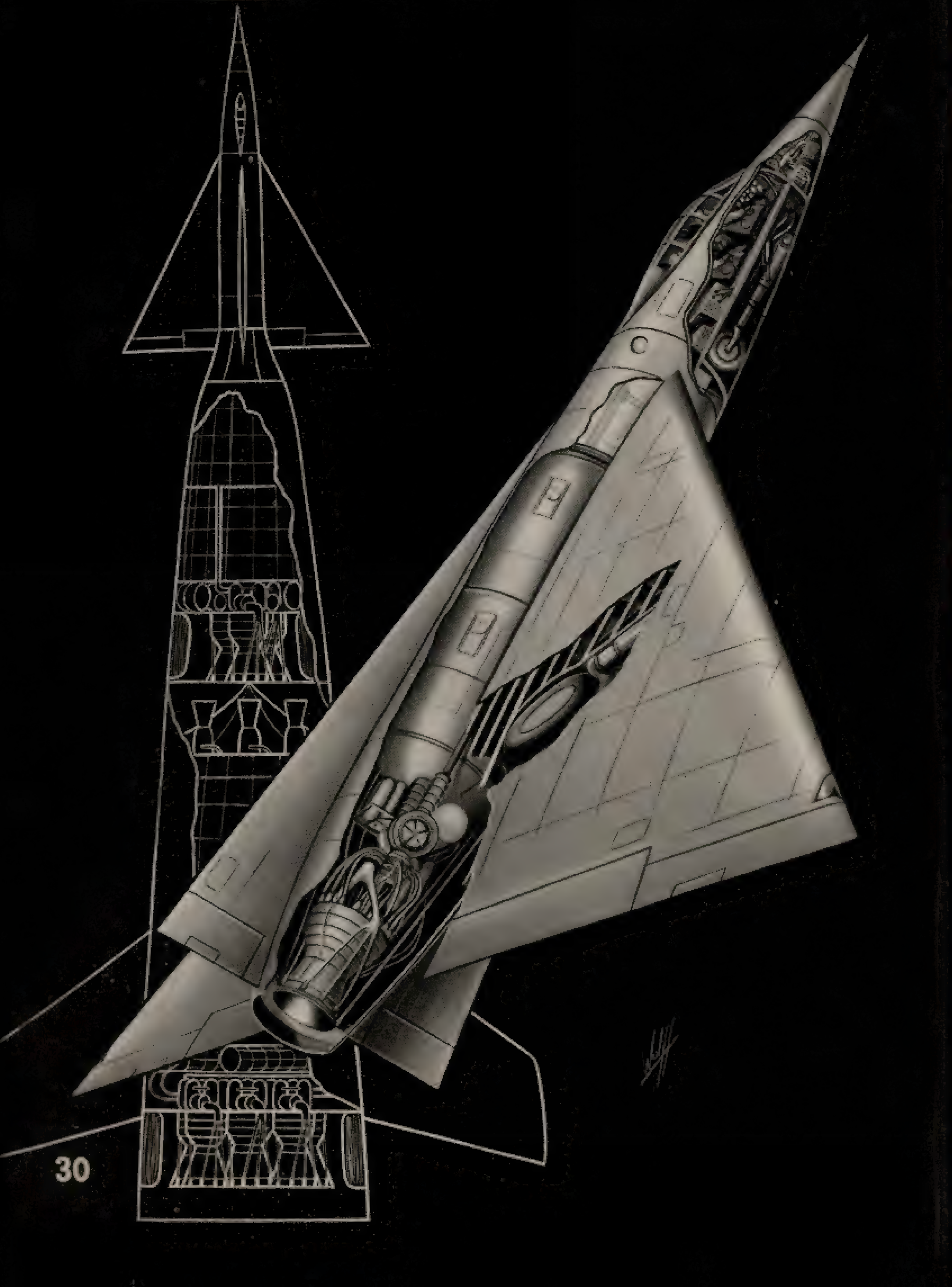




Take-off! On a pillar of flaming, radioactive exhaust gases, the nuclear space ship thunders off the earth and starts its journey through space to the moon. At the left is the gantry crane employed for servicing the great space ship and at far right can be seen the control centre from where the take-off operations are directed. **25**

Thirty thousand miles out in space, with the massive sphere of the earth partially eclipsing the distant sun; near the centre of the earth is the reflection of the moon. The space ship can be seen as it "coasts" in free fall towards the moon near the upper right of the planet. **26**

The first landing on the moon. Stern first, the atomic space ship descends to the moon's surface with its powerful rocket motors gradually decelerating it until it will land slowly on the pumice-covered rock of earth's satellite. **27**

To test the controllability and aerodynamic principles of the full-scale third-stage space ships, the latter will be towed aloft by large jet bombers and the tow rope released when the empty, manned space ship is thousands of feet above the earth and moving at several hundred miles per hour. **28**

Following the glide and powered tests of the third-stage space ship in towing operations, initial rocket-powered ascents from the earth will be carried out. During these tests the manned third stage will be borne aloft by a booster stage specially designed for this purpose. One of the main purposes of these flights will be to familiarize the crew with power operations; during the ascents faults inherent in the design can be determined before the actual flights into space are made. In this instance the fuel lines in the booster stage have clogged and burst, exploding into flame. **29**

A design proposal for a scaled-down, piloted three-stage space ship. **30**

Just as large rocket-powered supersonic research aircraft today are carried aloft for glide and power flights by B-29 and B-50 bombers, so the scaled-down two-man space ship can be borne into the sky beneath a large bomber for its first experimental flights. Here a stripped-down and modified B-36 bomber is seen climbing to 40,000 feet above the earth to release the space ship for its initial flights in the atmosphere. **31**

Any space-ship programme that contemplates the use of multistage vehicles must, in the interests of economic feasibility, plan for the continued re-use of the booster stages that are expended in the ascent from the earth. One proposal for recovery of these stages is to allow the empty booster to continue in a great trajectory above the earth after its fuel is exhausted, its velocity slowly decelerated by a great steel-mesh parachute released after power has been cut off. The fins of the booster stage and the parachute both provide sufficient stability to allow the booster to return to earth in a predictable path. **32**

of feet of movie film will be taken of the earth, sun, moon, and stars. Movie cameras in the ship will record the reactions of the first men in space; tape recorders will faithfully capture their conversation for scientists to study and the world to read and listen to. Spacesuits will be tested, pressurization equipment and procedures experimented with, in space.

These men will carry out the most fascinating experiment the world has ever known. When they return to earth, the first step in the actual conquest of space will have been completed. Soon afterwards the great multistage space ships, carrying larger crews and many tons of cargo, will thunder into the heavens to commence construction of a second moon for earth: an artificial, manned station in space orbiting endlessly about the planet.

Atoms and Space Ships

Many times since 1945, especially during the last three years, it has been suggested that we should by-pass the cumbersome, massive chemical fuel arrangements and utilize atomic energy to lift space ships off the earth. Advocates of nuclear power for space-ship propulsion criticize the anticipated consumption of hundreds of thousands of tons of fuel needed to build only one space station. They point to the nuclear reactor, actually operating in 1953, which will power the first atomic submarine; several such power plants are in the making. The strides made in aircraft nuclear power plants are listed as another notable advance in the process of harnessing atomic energy for propulsion purposes. An ever-increasing variety of reactors, piles, and other nuclear power sources are referred to as evidence of rapidly expanding knowledge in controlling the atom.

Before we embark on a crusade of criticism to do away with the

old-fashioned chemical rockets in favour of superpowered atomic-energy space ships, we must understand a little more about the nature of releasing and utilizing nuclear forces. The only known way of releasing atomic power is through its transformation into heat energy. Whether we consider the unearthly violence of the atomic bomb explosion, or the release of energy in an atomic pile, it is still heat. Controlling or harnessing the awesome energy of the uncontrolled atomic explosion, the atomic bomb, is out of the question. In the first few microseconds of the atomic explosion, the generation of heat reaches an unbelievable 40 to 70 million degrees Centigrade! This is heat on a scale so vast that it surpasses the temperatures in the interior of the sun. It is this same heat—instantaneously creating pressures of several hundred thousand atmospheres—which gives birth to the physical devastation created by the atomic explosion. The expansion of this heat from a localized area builds up such tremendous air pressure that a shock and blast wave explodes outwards in all directions. It is the force of this blast against physical objects and structures which destroys entire cities in one explosion. The release of energy in the form of nuclear radiations, while hazardous and often lethal to human beings, does not result in physical destruction. Heat, and its effects upon the surrounding atmosphere, are the hammer blows of the atomic bomb.

In a nuclear pile we also have an atomic explosion, or more correctly, an infinite number of localized atomic explosions; however, these explosions are controlled. Even these controlled explosions generate heat—much less, of course, than that caused by the detonation of an atomic bomb, but still heat of high degree. Water can be pumped through this atomic pile, evaporated, and a turbine driven with the steam. Electric power is generated which, through gear systems, drives the propellers of a submarine, surface vessel, or

an aeroplane. This is perfect for the purpose of propelling a ship through water or an aeroplane through the atmosphere. It is basically just what is done with the nuclear reactors now being tested for ships and aeroplanes, but propellers are useless in space. A space ship operates on the action and reaction principle; it must expel a mass in one direction in order to move its own mass in the opposite direction. Heavy water (deuterium) or liquid hydrogen can be piped through an atomic pile in a space ship, and the steam or vaporized hydrogen ejected through an exhaust nozzle, which is a modified rocket motor.

This is excellent paper theory but fails to work out well in practice. To generate sufficient thrust to lift and accelerate the considerable mass of the space ship, tremendous amounts of heat must be transferred from the nuclear reactor to the exhaust gas, the steam, or vaporized hydrogen. By raising to several hundred thousand degrees the temperatures generated by the controlled atomic explosions in the reactor, we would have a space ship capable of leaving the earth without successive steps, travelling to the moon, landing, taking off from the moon, and returning to earth.

The difficulty is that if we raise the temperature to several hundred thousand degrees, which is possible, the materials in the nuclear reactor and the space-ship metals in the vicinity will melt. Nuclear science has not yet advanced sufficiently to enable us to generate pile temperatures equivalent to those created by chemical reactions. For the interval of time in which a space ship lifts from the earth into space, chemical reactions are more efficient than nuclear propulsion. The velocity of the gases expelled from the atomic space ship would be less than that emitted from a vehicle using hydrazine and nitric acid or liquid oxygen and ethyl alcohol as propellants. This is not to say that the atomic space ship will remain a scientific

impossibility indefinitely. Nine years ago the atomic bomb was an unproved theory. Less than two years ago an operating nuclear reactor, for propulsion purposes, was no less a theory. Today, atomic drive for space ships is a theory. It may not be so tomorrow or ten years from now.

If we could solve this heat problem and could build an atomic-driven space ship, the upper section of the mighty vessel might contain the pressurized, instrumented crew compartment. Directly aft of the cabin are the fuel tanks and, farther below, the motors. The tail fins and swept-back wings are, of course, useless on the airless moon, but will be especially valuable when returning to earth.

Although step rockets are unnecessary with the projected atomic space ship, the vehicle would not maintain a vertical ascent during its climb from the earth. If a space ship were to climb with an acceleration factor of 3 gs immediately after lifting, and continued climbing vertically until its fuel was exhausted, at the end of that climb the forces acting on the crew might be as high as 35 gs.

The atomic space ship might follow a take-off procedure which entails motor operation for only three minutes and 50 seconds. During the climb the ship would ascend vertically and then gradually turn so that it was moving parallel to the earth's surface. Acceleration would continue until it had sufficient velocity to break free of earth's gravitational pull; it would then coast under its own momentum towards the moon, moving slower as the inexorable grip of earth attempted to pull it back.

In the highly credible motion picture, *Destination Moon*, an atomic-powered space ship followed this flight plan. *Brennschluss* occurred when the ship was 807 miles above the earth, moving out into space at more than 24,000 miles per hour. Forty-six hours after

the motors were cut off, the ship reached the moon. The time required for the trip from earth to moon depends entirely upon the velocity of the space ship at *Brennschluss*. If the ship left the earth at 25,000 miles per hour, it would reach the moon in about 115 hours. At 27,000 miles per hour, less than 20 hours are required for the full journey. The difference in time is represented by the initial velocity built up during the climb. Rocket engineers hesitate to assume initial velocities of 27,000 to 30,000 miles per hour for the reason that the additional velocity must be paid for dearly in terms of fuel transported several hundred miles off the earth.

During the earth-to-moon journey, the space ship is constantly losing velocity. For about nine-tenths of the distance between earth and its satellite it is moving rather slowly, but the gravitational attraction of the moon now becomes greater than that of the earth. The ship begins to pick up speed. If not slowed down, it would crash on the moon surface with a velocity of 5,200 miles per hour, plus the velocity it possessed when it reached the neutral point between earth and moon.

Gyroscopic controls would turn the ship around in space so that it approached the moon stern-first. If it left the earth at approximately 25,000 miles per hour, four minutes of continuous power at a deceleration factor of 1 g would be necessary to bring it safely down on the moon. At 2 gs, two minutes of power, commencing when the ship was 80 miles above the moon, would suffice. At 4 gs or greater, a shorter time of motor operation would be needed. The descent itself is entirely automatic. A radar altimeter in the space ship passes the exact distance of the vessel from the moon at all times to an electronic computer, which considers height, velocity, orbital movement, and other factors, and controls motor operation to lower the space ship at exactly the right speed.

There are more problems to perfecting the atomic space ship than those of heat transfer and the temperatures generated by the nuclear reactor. In a direct take-off and return from earth to moon, the space ship must carry sufficient fuel to leave the earth, land on the moon, take off from the moon, and maintain a fuel reserve for emergency manœuvres. If the vessel is designed to utilize its wings as a means of descent through the terrestrial atmosphere, landing without power, a minimum of emergency fuel reserve is required. If, however, a vertical-descent power landing is contemplated, then the ship must carry as much fuel for earth landing as it required to leave the earth.

Some engineers question whether an atomic-driven space ship will ever take off from the earth, pointing out that any exhaust gases must necessarily be radioactive. They contend that the blast-off area would be so radioactive after a take-off that human beings could not enter the contaminated zone, and that all the facilities and equipment necessary to construct, equip, fuel, and service the space ship would necessarily be abandoned. This claim may be cautiously refuted. No responsible scientist will say that we know enough about radiological contamination to predict exactly the thoroughness with which an atomic space ship would render uninhabitable any specified area. A take-off area could be so constructed that the base itself could continue to function normally, even if temporarily dangerous radiation were deposited on the ground. Several days or weeks after the ship departed, the natural rate of decay of radiological matter, plus decontamination procedures, would make the exact blast-off site safe for workmen. It is doubtful that even a fleet of a thousand atomic space ships would release into the atmosphere more than a small fraction of the dangerous waste substance emitted by the 40-odd atomic and hydrogen bombs so far exploded.

Confronted with the enormous weights of chemical fuels required directly to transport a crew of several men with necessary supplies, including fuel for the return trip, many a rocket engineer has proposed for the first moon trip a one-way, unmanned rocket. This proposal demands less of the engineer's ingenuity, for the final instrument-packed stage would be much lighter in weight than a final manned stage. No provisions would be made for a crew and such accessories as communications equipment, living space, food, water, air, or spacesuits; this would result in a vast decrease of over-all weight and fuel requirements.

When asked why such a ship should ever be built, since it would expend considerable material and money and would never return to the earth, the one-way moon-ship engineer insists that if nothing else, it will validate the calculations which prove that space travel is feasible. No more dramatic proof than the impact of an earth-launched robot on the surface of the moon can be visualized. Although interesting from a publicity and educational standpoint, the one-way rocket to the moon is basically a waste of effort. Years ago, before rocket technology had reached its present state, public acceptance and support of any rocket venture was non-existent. Today, with missiles by the thousands hurtling heavenward and a public which is becoming space-travel conscious, the need for such a venture has evaporated. The public no longer needs to be persuaded that men will reach the moon eventually.

5

The Space Satellite

Satellites in the form of instrument-bearing missiles, and space ships orbiting as temporary satellites, will pave the way years before the first manned space satellite is assembled far above the earth, a gleaming jewel of light to observers on the ground at dawn and dusk. Establishing the manned space station is one of the necessary major steps towards exploration of the moon and, finally, the planets. The limitations of chemical fuels, and the difficulties of adapting atomic energy for a space-ship drive, make it necessary to create a "way station" above the earth for outward-bound space ships. The satellite, adding to its myriad scientific activities, will serve as a construction base and fuelling station for the vessels which will cruise the solar system.

The dimensions of the satellite, its shape, distance from the earth, orbital velocity, construction materials, and similar factors will evolve from the particular missions assigned to the space station. Stress and balance mechanics, and the very considerable cost in materials and dollars of transporting several thousand tons of men and equipment to the chosen orbit, will influence the final design. The satellite's predecessors, orbiting missiles and space ships, will contribute immeasurably to final satellite assembly in space, furnishing scientists and engineers with the accrued data of in-space experiments.

The ultimate satellite design may be a giant sphere or some other physical shape dictated by the limits of the structural members. Most promising is the ring satellite which offers simple construction; sufficient interior room; safety and practicability; suitability for cargo-shuttle-rocket operation, probably the greatest protection against meteor penetration; and adaptability to artificially induced "gravity."

An outstanding advocate of the ring-satellite design, Wernher von Braun, has publicized his plans widely in the United States and European countries. Von Braun unfortunately justifies the effort to be expended in building the space station by the promise that the satellite will prove to be an invulnerable bombing platform which will enable us unfailingly to enforce world "peace and harmony." Many scientists, engineers, and publicists would contest the strategic thesis that peace can be maintained through a threat of physical destruction. Many writers have overlooked the sound and intricate detail of von Braun's work in planning his space station because of their preoccupation with what they consider a political perversion of a legitimate and serious scientific project.

Wernher von Braun has on many occasions been identified as the "world's leading rocket engineer." While he himself would not actually claim such a title—and no one person could be sufficiently proficient in all phases of rocketry and its allied sciences to warrant such distinction—von Braun certainly is one of the great leaders in rocket engineering. His studies on the subject of space satellites are not recent conceptions, but rather the development of an intense interest in the subject of rocketry, and actual participation in rocket development, prior to World War II, during the war, and in more recent years.

While the specifications laid down by von Braun for a space

satellite and its supporting shuttle-cargo rockets are a masterpiece of scientific prognostication, his suggested construction time schedules and financial estimates appear to be hopelessly optimistic. He may be justifiably criticized for underestimating the time which must elapse before the satellite is built, for his belief that no major calamities will occur during its construction, and for emphasizing the space station's supposed capacity for military domination.

The idea of an artificial station in space orbiting about the earth with the twofold purpose of serving the cause of science and visiting devastation upon this planet was conceived in detail more than 30 years ago. In the early 1920s the German Captain Hermann Noordung (the pen-name of the Austrian Captain Potocnik) envisioned such a platform in space. Noordung's installation was actually a trio of satellites, comprising living quarters, a scientific workroom and observatory and a power plant, all connected to each other by flexible air cables and pipelines. Assembled at a height of 22,000 miles above this planet, this device was intended to revolve about the earth once every 24 hours. Inside the living quarters, a large wheel or ringlike structure 100 feet in diameter, scientists and spacemen would live under artificially induced gravity; the wheel would rotate on its own axis once every eight seconds, thus creating a sensation of partial gravity at the rim through centrifugal force. The rim of the wheel would contain living necessities. Men would enter and leave the satellite through elevators and stairwells leading from the wheel rim to a centrally located airlock. Power to run the satellite machinery would be obtained from the energy of a large circular solar mirror transmitted through flexible power cables to the living quarters.

A cylindrical observatory for scientific investigation and research would be maintained a short distance from the personnel station.

Special telescopes and cameras trained on the earth were to observe weather conditions and other phenomena and report in detail to ground stations. Anticipating present-day astronomers, Noordung explained in detail the value of such observation. Powerful telescopes beyond the hindering atmospheric blanket of air, dust, and water vapour would immeasurably enlarge man's knowledge of the universe. If physically able to withstand the frightening forces of acceleration, astronomers would be transported by rocket to the satellite orbit to study magnitudes, distances, motions, and the physical constitution of heavenly bodies.

The parabolic mirror and powerhouse would supply energy for the other two stations in space. Its operation would duplicate the processes of an ordinary steam turbine system. The sun's heat striking the mirror would vaporize liquid oxygen, driving a turbine coupled to an electric dynamo. Power cables stretched through space would supply current directly to the observatory and living quarters. Leaving the turbine, the vaporized liquid oxygen would circulate to a cooling unit in the shadow of the installation, where the temperature would be several hundred degrees below zero, and would then be pumped back for reuse in the mirror.

In 1929 Professor Hermann Oberth, one of the great names in early rocket development, devised another arrangement for a space satellite. Enlarging upon Noordung's plans, Oberth recommended a station circling the earth every four hours, orbiting at a distance of 600 miles. Oberth detailed the transport of satellite structural members and equipment in cargo-shuttle rockets. The shuttle vehicles would dump their cargo in space; when sufficient material had been ferried to the free-fall orbit, workmen would assemble the satellite. The German designer even went into construction details, describing

how workmen in spacesuits would be able to move massive equipment without difficulty.

A giant concave sun mirror, constructed of small movable facets of metallic sodium mounted on a wire network in a circular frame, constituted another Oberth proposal. A subsequent British development has been suggested by Smith and Ross. Sodium was considered most favourable for use in the vacuum of space; a silver-white alkaline metal, its reflective properties were about the best known in 1929. Oberth made detailed plans to assemble the mirror in space; free cables, attached to a rotating central space ship, were to be spread out into a huge cable network. Metallic sodium strips would be secured to these cables like sheet metal; adjustment of the cable-mounted facets by electromagnetic or similar means would reflect the sun's rays into a single beam of intense heat, or permit the heat reflection to be dispersed over a larger area.

The satellite was thought of as a weapon many years ago. Oberth suggested that the concentrated solar-energy beam could evaporate water supplies, burn entire cities to ashes, or set fire to hundreds of thousands of square miles of enemy forest and food-growing lands. He also recommended beneficial employment of this great energy source to control weather, evaporate useless water or melt ice fields, or illuminate wide areas of the planet surface at night.

Perhaps the most visionary of Oberth's proposals was the recommendation that the space station be equipped as a refuelling depot for space ships departing from the earth for interplanetary destinations. Greater payloads, wrote the far-sighted German engineer, could be attained for space ships by reducing the blast-off fuel load and substituting valuable cargo for the fuel normally consumed. Six

hundred miles above the planet, accompanying cargo ships would refuel the planetary-bound space ship, which would leave the earth behind with almost a maximum fuel load.

More than two decades ago Count Guido von Pirquet, undoubtedly inspired by the elaborate plans of Noordung, recommended a space-station project consisting of three individual satellites. Included was a so-called inner station, a manned observation satellite designed to scrutinize the planet from a height of 470 miles. Whirling about the earth in an orbit of only 27,000 miles, the inner station would complete a planetary revolution once every hour and 40 minutes. A refuelling and contact base for interplanetary space ships, the second satellite would orbit at a distance of 3,100 miles. Completing a single planetary revolution once every three hours and 20 minutes, the outer station would follow an orbit of 44,600 miles.

Most ingenious of all was von Pirquet's third satellite, a transit station maintaining contact between the inner and outer satellites. Following an elliptical rather than a circular orbit, the transit station would approach to within 470 miles of earth and swing out into space to a maximum distance of 3,100 miles. Over a period of years this would represent enormous savings in chemical propellants; a space ship from the earth wishing to reach the contact satellite orbiting at 3,100 miles need only contact the transit station when it was closest to earth. Men and equipment would be transferred to the transit station; soon afterwards they would leave their "shuttle" to board the outer satellite.

The substance of the German's proposals has withstood time well. Many points originally projected have been abandoned or modified by modern scientific discoveries. As a single example, early proposals for communicating between the space station and the earth envisioned the use of a sun-reflector blinker system employ-

ing the Morse code. This has been abandoned in favour of advanced electronics, which today ensure simple and effective communications from earth to satellite.

When the U.S. Department of Defense in December of 1948 revealed the existence of an earth satellite-vehicle programme, many of the German proposals, made when rocket engineering was not yet a science, came to life. The satellite briefly described by the Department of Defense was projected to circle the planet at a distance of 22,300 miles. It was proposed to employ it as a robot control site for terrestrial bombardment; the old suggestion to employ giant mirrors to burn cities, forests, and food and water supplies, as well as to create chaos and devastation throughout an enemy's homeland, was revived.

Von Braun, therefore, has a rich and imaginative background out of which he perfected his own painstakingly detailed satellite design. Imagination alone is not his only asset; his extensive activity in rocket research and development is unsurpassed by that of any other man.

All satellite proposals follow a basic pattern; they include development of cargo space ships to transport men and equipment to the desired orbit, construction of the satellite, and, eventually, survey and exploration of the moon. In discussing the most elaborate satellite design yet made public, that of von Braun, the reader should keep in mind that many equally capable rocket engineers feel strongly that his proposals are of a scale beyond the possibility of realization. They contend that if his project, involving a 25-year programme and the expenditure of more than five billion dollars, were to fail, the resulting flood of public opposition to what would be called a senseless waste of money might delay for many years the conquest of space. These engineers believe that the project can be

accomplished on a lesser, more practicable, and less expensive scale. In all its ramifications, however, von Braun's satellite project represents some of the most advanced and capable thinking on this subject. The following description of the cargo space ships and the 250-foot-diameter satellite constitutes the essence of the von Braun project.

The Space Ship

Before the first giant cargo rocket delivers supplies and equipment to the satellite orbit, these space ships will have made hundreds of experimental flights under every possible condition anticipated by rocket engineers. The von Braun satellite calls for an orbit 1,075 miles distant and a permanent velocity of 15,840 miles per hour; at this height and speed it will circle the earth once every two hours completing 12 planetary revolutions per day. With a diameter of 250 feet, it will have a weight of several hundred tons. Since a cargo delivery by shuttle rocket is expected to weigh approximately 36 tons with a crew of six, each rocket involves physical size, motor thrust, and fuel expenditure of a magnitude which could easily send a smaller space ship safely on its way to the moon.

The three-stage von Braun space ship extends 265 feet from the base of the first-stage stabilizing fins to the needle nose of the final stage. Over-all weight is 7,000 tons, equivalent to the displacement of a fully equipped naval cruiser. All three stages are powered by multiple sets of rocket motors which burn hydrazine and nitric acid fuel combinations. Fuel is forced under pressure into the motors by hydrogen-peroxide steam-powered turbopumps.

The space ship is assembled on a large, movable launching-platform which rolls along the ground on special steel tracks. The

arrangement is similar to the trackbeds of giant cranes found in shipyards and steel mills. The space ship is assembled beneath a great gantry crane which permits access to the outer skin of the rocket and facilitates entry within the ship at any height. Servicing, instrumenting, outfitting, and fuelling are performed from the gantry crane and accessory facilities.

Serviced and ready for launching, the crew resting on acceleration couches within the pressurized cabin, the space ship is rolled away from the gantry crane on its movable platform base. The launching-platform beneath the first-stage motors has a large circular area removed from its centre just before blast-off. Before the motors are fired, the platform rolls directly over a deep firing pit. In the ground beneath the circular well cut out from the platform is a deep, concrete-lined shaft. When the motors fire, the flaming exhaust gases funnel into this shaft, are diverted to curved underground concrete tunnels, and finally are harmlessly dissipated into the air hundreds of feet from the launching-platform. This arrangement not only prevents the superheated gases from splashing the launching-area, but also makes certain that the space-ship take-off will in no way be detrimentally affected.

The first stage comprises 75 per cent of the rocket's total mass. The diameter of the first stage at the base, not including the sharply swept-back fixed fins, is 65 feet. Fifty-one rocket motors, including 12 swivel-mounted motors which alter the attitude of the ship from its vertical ascent, generate 14,000 tons of thrust. Burning for 84 seconds, these 51 motors consume and dispel as exhaust gases 5,250 tons of rocket fuel. Between the fuel tanks and the banks of rocket motors are the two hydrogen-peroxide tanks which supply turbopump power to feed fuel into the rocket motors by force. A great steel-mesh parachute, connected to the rear section of the first stage,

is packed tightly round the rocket base. This is released immediately after the rocket motors are throttled back to minimum cruising speed to permit the second stage to break away and move ahead. Also at the base of the first stage are banks of solid-fuel rockets. As the steel-mesh parachute drops the cumbersome empty stage into the ocean, proximity fuses set off the solid-fuel rockets just before contact with the water, breaking the fall and allowing a non-damaging drop into the ocean. The spent stage will remain afloat, since buoyancy is provided by the empty fuel tanks until it is retrieved by special salvage ships.

Just before the first-stage fuel is exhausted, the rocket's 51 motors are throttled back to barest cruising power. Immediately, the 34 rocket motors of the second stage burst into life. Already moving with great velocity high above the earth, the remaining space-ship sections are hurtled even faster and higher into space. During the total powered operation of the second stage's 34 motors, 770 tons of fuel are consumed to produce a thrust of 1,750 tons. Twelve rocket motors are mounted on special swivel brackets in four units of three each, to further increase the horizontal attitude of the climbing space ship. There are no external fins or guiding surfaces. When the fuel is almost exhausted, the motors are throttled back and the steel-mesh parachute is released.

The five rocket motors of the final, manned stage splash flame over the receding second stage. Ninety tons of fuel, including reserves, are sufficient to raise the speed of the piloted stage into what is almost a permanent orbit. Later, when the space ship's final stage has coasted to a height of 1,075 miles above the earth, a brief power manœuvre will add speed to the space ship and set it in its permanent orbit about the earth. Four of the five rocket motors are utilized for the main thrust; the fifth motor is employed for cruising and directional control.

This final stage is essentially a combination space ship and aeroplane. Its broad, swept-back wings and conventional external control surfaces are useless in the airless vacuum of space, but they will be indispensable when the ship returns to the atmosphere to land. The aerodynamic design involved is adapted to the requirements of a large, pressurized space ship; the result is a tail-first *canard* design.

The forward "wings" function as horizontal stabilizers and elevators. The main wings embody conventional landing flaps, ailerons, and leading-edge slots. The vertical stabilizers and rudders are located midway between the fuselage and the wing outer edges. The main gear legs of the tricycle undercarriage employ the small, double-wheel sets so common in modern jet bombers. Six men are normally accommodated within the spacious pressurized cabin, complete with portholes for the crew members. The navigator uses an outsize pressure bubble for in-space navigation and to plot a flight plan during the return to earth. Between the pressurized cabin and the fuel tanks lies the voluminous cargo compartment, in which 36 tons of equipment and supplies are carried.

Just as the miniature three-stage space ship flew in glide tests and powered flights and orbited about earth for several days, so the full-scale ship will be put through gruelling tests. Too large to be carried beneath a bomber, the third stage is towed aloft by jet bombers. The space ship, in this case essentially an aeroplane, is towed to great heights to test its aerodynamic characteristics and controllability and to eliminate the minor defects inherent in any new design. Later the space ship will be towed into the air once more, this time with fuel tanks filled. Combinations of jet power and solid-fuel rocket-assisted take-off will lift the heavy machine into the air. Once the space ship is well above ground, the nylon tow rope will be cut free and the rocket motors started to begin the experimental powered flights. Subsequent test flights will include powered take-off

from the ground, the big ship functioning as a rocket-powered aeroplane.

Extensive air-base facilities with maximum-length runway take-off and landing area are necessary for the test flights. Edwards Air Force Base in the California desert provides miles of natural, rock-hard runways presently used for aeroplanes capable of a speed greater than 1,300 miles per hour.

It will be necessary to develop emergency procedures in the event of in-flight or in-space accidents. Unpowered dead-stick landings will give the pilot experience in flying and landing his ship in the event of power failure. Instruments may malfunction; electrical connections may split. Jammed controls can force the crew to abandon their craft in flight. Following its test flights in the atmosphere, the space ship will be put through extreme atmosphere and in-space flights. Further testing of equipment is vital. Rocket-fuel pumps may be blocked, forcing the pressure lines to burst. Fuel lines feeding the white-hot motors may burst into sheets of flame. Emergency procedures, such as abandoning the space ship or prematurely jettisoning the booster stages, must be evolved and put into practice before the satellite construction programme is started.

No pressurized aeroplane or space ship will ever be free from the possibility of explosive decompression. A porthole blown into space will allow the ship's atmosphere to explode violently through the rupture. Only seconds in which to act and survive are available. The emergency measures most effective in explosive decompression must be determined. It may develop that it is necessary to wear a fully pressurized spacesuit during the climb and while the ship is in space. While this arrangement is conducive to safety, it also presents complications, since the movement-restricting spacesuit will seriously hamper the crew members in their control operations.

To meet explosive decompression von Braun recommends the use of pressurized capsules which would snap shut and seal a man within. Seating arrangements, controls, and pressurization for each crew member would be so designed that in an emergency a man enclosed within his steel cylinder could continue to perform his duties. Strapped into his seat, the crewman presses buttons at the end of the chair armrests; the seat immediately moves to a vertical position and the two halves of the metal cylinder slide together on rails and snap shut. Controls and pressurization equipment would be connected to the capsule through a single multi-unit plug, easily disconnected and patterned after fighter aircraft equipment. The ship could be controlled from within the sealed capsules, since vision is provided for through special transparent material at eye level.

In decompression the crew would remain within their capsules during powered ascent until they reached the space station where other spacesuited men would either repair the ship and restore pressure or remove the capsules from the damaged ship for transfer to the pressurized satellite. In case of an accident making further ascent impossible, the crew would make an emergency descent to earth, remaining within their sealed capsules until they reached the lower atmosphere.

In the event that an exploded fuel tank, jammed controls, or some similar disaster made operation impossible, the sealed capsules would serve as escape units. Encased in the cylinders, the men would be ejected from the hurtling space ship. If the cylinders were blown clear when the ship was climbing at an angle, they would continue on with the velocity the ship had attained when it was abandoned, perhaps as much as 13,000 miles per hour. With this momentum, they would continue coasting upwards through space, describing a great arc before descending to the upper atmosphere.

At this speed, air friction would raise the temperature of the capsule's skin by hundreds of degrees. With his escape unit glowing red from this great heat, each occupant would be protected by layers of steel, glass-wool insulation, and lumps of solidified air. A steel-mesh parachute would brake and stabilize the cylinder in its descent through the atmosphere. Several seconds before impact with the ground or water, a proximity fuse would fire solid-fuel rockets to drop the cylinder gently into the ocean. Radio equipment would automatically transmit emergency messages to waiting rescue ships to pin-point the location of the floating cylinder.

The initial trip to 1,075 miles above the earth will not involve the start of satellite assembly but will be a final dress rehearsal of the space-ship operation. The ship will remain in space for several days to conduct scientific and equipment experiments and to provide verification of a stable, permanent orbiting height and velocity. With the tests completed, the ship will return to earth. Other space ships, their cargo holds jammed with satellite construction material, will be waiting to establish the first way station to space.

A vast scientific army spread out across the globe will co-ordinate its activities for the launching. Computers will have determined the precise take-off moment at which the ship will leave the earth. Radar stations, theodolites, and telephoto cameras operating on ships at sea and in aeroplanes will track the ship every second of its climb from installations on the ground. On the ocean surface below the rising arc of the flight path, cumbersome salvage ships escorted by radar search vessels wait to track and retrieve the jettisoned booster stages. Speedy destroyers will watch for any signs of an accident, ready to pick up crew members if they are forced to abandon the rocket.

There are enough personnel and facilities surrounding the

launching-base to make up a fair-sized city. Living, feeding, transportation, recreation, communication, and administrative facilities for the army of construction workers, technicians, military forces, scientists, press members, and supporting personnel are spread over an area of many square miles. Labourers, engineers, firemen, utility workers, police, and hundreds of operators are required to maintain the launching-base "city." Since the satellite operations involve an indefinitely continuing programme, families must be housed and cared for. To facilitate cargo and personnel transportation, a large commercial and military air base is necessary. Extensive highway systems for trucks, cars, and buses must be constructed and maintained. Fuel-tank storage areas for the space-ship launchings and logistical support of military, commercial, and private facilities are necessary. Rail-yards capable of handling hundreds of tank and freight cars must be provided. Since the booster stages will be jettisoned in the ocean, the launching-site located near the coast will require a sheltered harbour and good docking facilities.

If ever we begin the conquest of space on a scale recommended by von Braun, such mammoth operations will be unavoidable. It is easy to understand why rocket engineers insist upon an exhaustive study of all aspects of space travel before the attempt to conquer space is made. The resources of the entire American nation must support the years-long project, and much of the national economy will inevitably be harnessed to handle the myriad ramifications of the satellite programme.

Take-off!

Firing time is only minutes away. Sirens throughout and surrounding the launching-base scream their final warning for the area to be cleared of all personnel. For hundreds of yards surrounding the

launching-platform the area is deserted. One minute before launching, red flares burst high above as the final warning. Millions of electronic connections click rapidly in observation posts, radar and theodolite stations, aboard ships and planes, and in control rooms. In the master control room the second hand of the electronic timer ticks away the few remaining seconds. The hand moves to eight—seven—six—five—four—three—two—one—FIRE! A Niagara of flame suddenly gushes from the base of the space ship into the concrete shaft below. Smoke and flame erupt skywards hundreds of feet away from the blast exhaust pits. The sound of the motors is deafening even miles away and is so powerful that the beating thunder is more sensed by the body than heard by the stunned ears. The sound smashes across the area, disappears over the ocean, and many seconds later rebounds from distant mountains.

Slowly, almost imperceptibly, the 7,000-ton monster lifts off the launching-pad. Only 15 feet in the first second. Flame rolls across the pad as the ship rises. Soon it is moving quickly, and less than 30 seconds later appears as a tiny, searing fireball quickly vanishing in the heavens. A smoke trail, twisting and winding as it is dismembered by the lateral winds of the upper atmosphere, marks the climbing arc.

Aboard the space ship the six crew members are forced back into their couches by the climb. Soon the automatic pilot tilts the thundering ship from the true vertical into a shallow climb. When the 265-foot ship is 25 miles high, it is climbing at an angle of 20·5 degrees. Eighty-four seconds later and 5,250 tons lighter, the space ship is moving into space at over 5,200 miles per hour, slightly faster than the velocity of the Bumper fired in February of 1949. With almost all their fuel exhausted, the first-stage motors are throttled back. The second-stage motors cut in, their exhaust flames washing

over the now-receding first stage. One hundred and twenty-four seconds later, the space ship is nearly 40 miles above the earth and moving at 14,364 miles per hour. As the second-stage motors are throttled back with nearly empty fuel tanks, the launching site is 332 miles behind.

The five motors of the manned space ship burst soundlessly into life and hurl the space ship forwards for 84 seconds before they are cut off. The ship is moving out into space at 18,468 miles per hour, coasting upwards and forwards 63·3 miles above the planet. Inside the winged vessel the weightless crew members rise against their restraining straps.

Above the earth 1,075 miles, less than one hour after take-off, the space ship reaches the peak of its climb. It is half-way round the globe and gravity has reduced the forward velocity to only 14,770 miles per hour. The space ship could remain at this height and velocity while the construction of a satellite began. If assembled under these conditions of velocity and height, however, the satellite would whirl in an elliptical rather than a circular orbit about the earth, and would periodically drop back to 63 miles above the planet. After many thousands of these elliptical revolutions, the tenuous resistance of extreme-upper-atmosphere particles would slow the satellite down. The cumulative effect of such resistance would eventually cause the satellite to crash.

The space ship must go through yet another power manœuvre to compensate partially for the loss of forward velocity and establish it in a circular orbit making a full revolution about the earth once every 120 minutes. A velocity of 15,840 miles per hour is needed. Just as the unmanned satellites which preceded the space ship might have tumbled end over end as they climbed beyond the reach of atmospheric resistance which would act on the rocket fins, and had

to be corrected before establishing an orbit, so the manned space ship must first be oriented along its flight path before power is applied. If this alignment with the orbit is incorrect, the power manœuvre will serve only to throw the ship away from its orbit.

In the elliptical orbit the space ship is capable of making only three independent movements: banking along the longitudinal axis, moving up and down, and turning to the left and right. The navigator, using two fixed stars for reference points, "locks" the swivel-mounted telescopes of the positioning mechanism, by using photoelectric cells, to these stars. By establishing the nose of the space ship as the "horizon" and the two stars as reference points, he creates a three-dimensional co-ordinate system with the space ship as the centre.

The three degrees of space-ship movement are checked against the celestial reference points on the navigation maps. The next step is to align a suspended gimbal system, consisting of three gyroscopes, so that it co-ordinates with the proper orbit. When the gyroscopes in the suspended gimbal system inside the space ship are matched with the charts and photoelectric cell telescopes, the navigator sets in motion three electrically operated flywheels. Slowly the great ship turns in space to match exactly the position of the gimbal system. When these two are perfectly aligned the rocket motors are fired for precisely 15 seconds. The ship adds 1,070 miles per hour to its velocity and is now established in the two-hour circular orbit.

The satellite swings about the earth, covering a distance of 264 miles every minute. When space ships climbing from the earth attempt to intersect the position of the satellite in its orbit, additional in-space manœuvres must be made. If the climbing space ship arrives at the orbit only seven seconds too late or too early to intersect the satellite's position, it will be more than 30 miles away! Even

the most reliable instruments cannot be expected to deliver the precision manœuvres during climb necessary to place the space ship close to the satellite. Additional control by the pilot and navigator must bring the space ship close enough to effect cargo and personnel transfer between the ship and satellite.

Obviously, the performance figures and construction details of the space ships proposed by the eminent Dr. von Braun are the result of long and painstaking study. Since the subject of space ships and space satellites is as yet more speculation than science, and since no manned space ship has yet been built, it is inevitable that mistakes in theory will be made and that equally capable rocket engineers and scientists are liable to differ with the data presented by this pioneer.

Leslie R. Shepherd, Technical Director of the British Interplanetary Society, and A. V. Cleaver, one of Britain's leading rocket engineers and a past president of the British Interplanetary Society, have publicly opposed several of von Braun's contentions. The cost of establishing the station in space has been estimated by von Braun as four billion dollars, assuming that the expensive lower steps of the dozen or more cargo rocket craft would be recoverable through parachute drop for repeated use. Shepherd and Cleaver are of the opinion that even if only 10 per cent of these booster stages were lost through parachute recovery, and they consider this a very optimistic assumption, then the cost would be measurably increased.

How von Braun arrives at a cost estimate of four million dollars each for his proposed earth-to-orbit shuttle rockets is not revealed. These proposed vehicles have an empty weight of nearly 1,000 tons and involve the production and maintenance of precision instruments and electronic and other equipment. Those familiar with aircraft

production costs can realize how wildly unrealistic this figure is. Just what *each* space ship would cost in dollars is a figure difficult to estimate accurately, but the amount might well exceed 75 million dollars. As a means of comparison, the first experimental Boeing XB-52 Stratofortress eight-jet bombing aeroplane cost American taxpayers no less than 22 million dollars!

A single all-weather jet interceptor, carrying two men and electronic and radar equipment, costs approximately one million dollars. The von Braun estimate of four million dollars for an empty-weight space ship of 1,000 tons is not realistic. Equally important, since this is a project which must continue for several years, we must contemplate the loss through accident not only of booster stages but of the entire three-stage space ship or several space ships.

Von Braun's ten- to 15-year estimate for completion of the space station is inconsistent with the development time of large military aircraft. The ten-engine B-36 intercontinental bomber, for example, was on drawing-boards before World War II began, yet the ship did not fly until after the war. It required several additional years to eliminate minor defects from the world's largest bomber to make it a combat-worthy aeroplane. Through the cost-reducing aspect of mass production, costs have been pared down to approximately three million dollars per aeroplane. The latest in scientific safety aids are employed to reduce accidents, yet B-36s still crash. There exists not the slightest authority to justify the acceptance of three major assumptions: (1) that the satellite could be established in space within ten years—30 is more likely; (2) that a 1,000-ton empty-weight, elaborately equipped space ship could be constructed for a figure even approximating four million dollars; or (3) that operational accidents both on the ground and in the air would not extend the anticipated time limit of the project and add hundreds of millions of dollars, perhaps billions, to the anticipated cost.

Assembling the Satellite

When the first cargo rocket shuttles to the 1,075-mile-high orbit above the earth, the exact position of the satellite to be built will be established. Inside the space ship the weightless crew members don their spacesuits. This is a slow process as each man repeatedly checks every item of equipment; after he is satisfied with his suit, pressurization, and equipment, each crew member is carefully inspected by the other men. Suit-pressure readings, sealed joints, communications equipment, glass visor, tools, safety lines, and boots are all painstakingly inspected, for even a small, unnoticed gash in a man's spacesuit means agonizing death by explosive decompression.

Outside the space ship, each man fastens securely a thin but strong line to a projecting grapple on the ship's outer skin; this in turn is secured to the spacesuit. Since the men are moving with the momentum of the ship in free fall, they experience no sensation of movement and are actually weightless. But the force of inertia still applies, and a man could unknowingly push himself away from the space ship. Unless he were attached to the ship by the safety line, he might drift beyond any possible recovery, to die in agony when his air supply was exhausted. To assist the crew in their work while moving about on the surface of the space ship and in the cargo hold, each spacesuit boot has a sole and heel plate of magnetized steel. This enables them to stand when working; without it, their exertions would send them rebounding in a direction opposite to any application of physical force.

Unless we develop better insulation materials than are at present available, the arms of the spacesuits will not terminate in the familiar

gloves or mittens, but more probably in "hands" grasping tools —such as hooks, grapplers, and pincers, suited to carry out specific tasks.

Communication will be effected primarily through personal radios strapped to the spacesuit, with sending microphones and receivers built into the helmets. Lightweight sets with clear sending and receiving power over a distance of several miles, they are battery-operated and allow co-ordination of activities in the soundless vacuum of space. If two men are close enough to touch each other, the sound transmitted by the spacesuits and their bodies will allow conversation without radios. However, this would hardly be continuously practicable.

The crew begins the transfer of construction equipment and materials from the ship into space. The first ships carry only the basic assembly parts: metal beams, cables, and special welding, riveting, and power equipment which will work in a vacuum. Later the machinery for use inside the satellite, living equipment, air tanks, and all the necessary material to establish the satellite as an operating base will be integrated into the skeletal framework.

The men heave and push to move the bulky cargo loads out of the cargo hatch. Although weightless, the cargo still is subject to inertia and cannot be handled easily by the crewmen. If a man were to push against a crate with an earth weight of 3,000 pounds it would move slowly in the desired direction. The crewmen, however, would rebound in the opposite direction with even greater speed. Portable rocket motors or small, efficient reaction motors would remedy this defect. To manœuvre in space a man would place the back of the motor against his midriff and press the operating button or handle. With the motor operating under even slight power the spaceman would move in the opposite direction.

This is not as simple as it sounds. Aiming the rocket nozzle at any improper angle would send the spaceman veering away from his destination. Since orientation in space is almost impossible, incorrect positioning of the motor unit against the body would throw the spaceman into wild gyrations. He might spin in circles, whirl like a cartwheel, or turn end over end. This is another reason for sending the first space ships to orbit above the planet for research purposes; the first men in space will experiment with such equipment and pass on the results of their experience.

The probability of unpredictable action when the portable reaction motor is used in space demands that a safety line be secured to the space ship or satellite. Unless a man has extensive experience with his portable motor, he might go tumbling end over end away from the ship; only by expert manipulation of his motor can he stop this movement. A man inexperienced at space manœuvring might yield to panic and press hard on the motor switch. Attempting thus to stop his wild flight, he might send himself to certain death. If he were secured to the ship he could pull himself back, hand over hand. That safety line is the spaceman's link to survival.

As the cargo is removed from the first space ship, a second ship is dispatched to the orbit. Construction and assembly are undertaken immediately, in order that no time be lost in making the space station ready for permanent occupancy. The ring-satellite design advanced by von Braun is 250 feet in diameter with three "decks" for operational and living-quarters. The design envisions that sections of flexible nylon and plastic fabric will be "blown up" with their atmosphere, establishing a surface rigidity because of the internal air pressure of eight pounds per square inch. First, the outer girders and beams are assembled to form the satellite skeleton. If the nylon-plastic sections are pierced at any time after "inflation," the skeleton

33 The three-stage space ship envisioned by Dr. Wernher von Braun, who has been carrying out an extensive publicity campaign in favour of space travel *now*. Von Braun's three-stage space ship is designed to carry a crew of about six men and 34 tons of cargo to an orbit 1,075 miles above the earth, where a space satellite will be assembled, to whirl about the earth at a velocity of 15,840 miles per hour.

34 The first of the full-size space ships will enter the planned satellite orbit above the earth and remain in space for several days to a week. During this period special equipment will be tested. Spacesuited men will leave the holds of the great vessel to experiment with personal equipment and to conduct experiments with reaction motors.

35 The von Braun third-stage design as it would land following its descent from space. The journey from the 1,075-mile orbit to the landing-strip will be a hazardous adventure of 18,000-mile-per-hour velocity, temperatures on the outer skin of the spaceship as high as 1,200° Fahrenheit.

36 After the in-space physiological and equipment tests are completed, the work of assembling the space satellite will get under way. In this case the satellite is of the popular "ring design," 250 feet in diameter.

37 A combination of proposals from both sides of the Atlantic. The space satellite depicted in its final stages of construction is the design proposal of von Braun, the space ships indicated a variation of a delta-wing suggestion by R. A. Smith of the British Interplanetary Society.

38 One of several space-satellite designs shown in completed form, with two shuttle rockets orbiting with the satellite. Atop the central hub of the satellite is the great mirror and sun boiler, which uses the heat of the distant sun to provide the necessary power for the satellite's machinery and equipment.

39 One of the principal activities of the station in space will be to conduct exhaustive astronomical surveillance of the cosmos.

40 More than 30 years ago proposals were made in Germany for various designs of space satellites, among which was included the construction of a giant mirror orbiting about the earth. The solar reflecting mirror has also been mentioned in official United States Department of Defense releases concerning investigation into the possible use of space satellites by the United States. The giant mirror design as illustrated by R. A. Smith of the British Interplanetary Society has been modified in this picture by artist Fred L. Wolff.

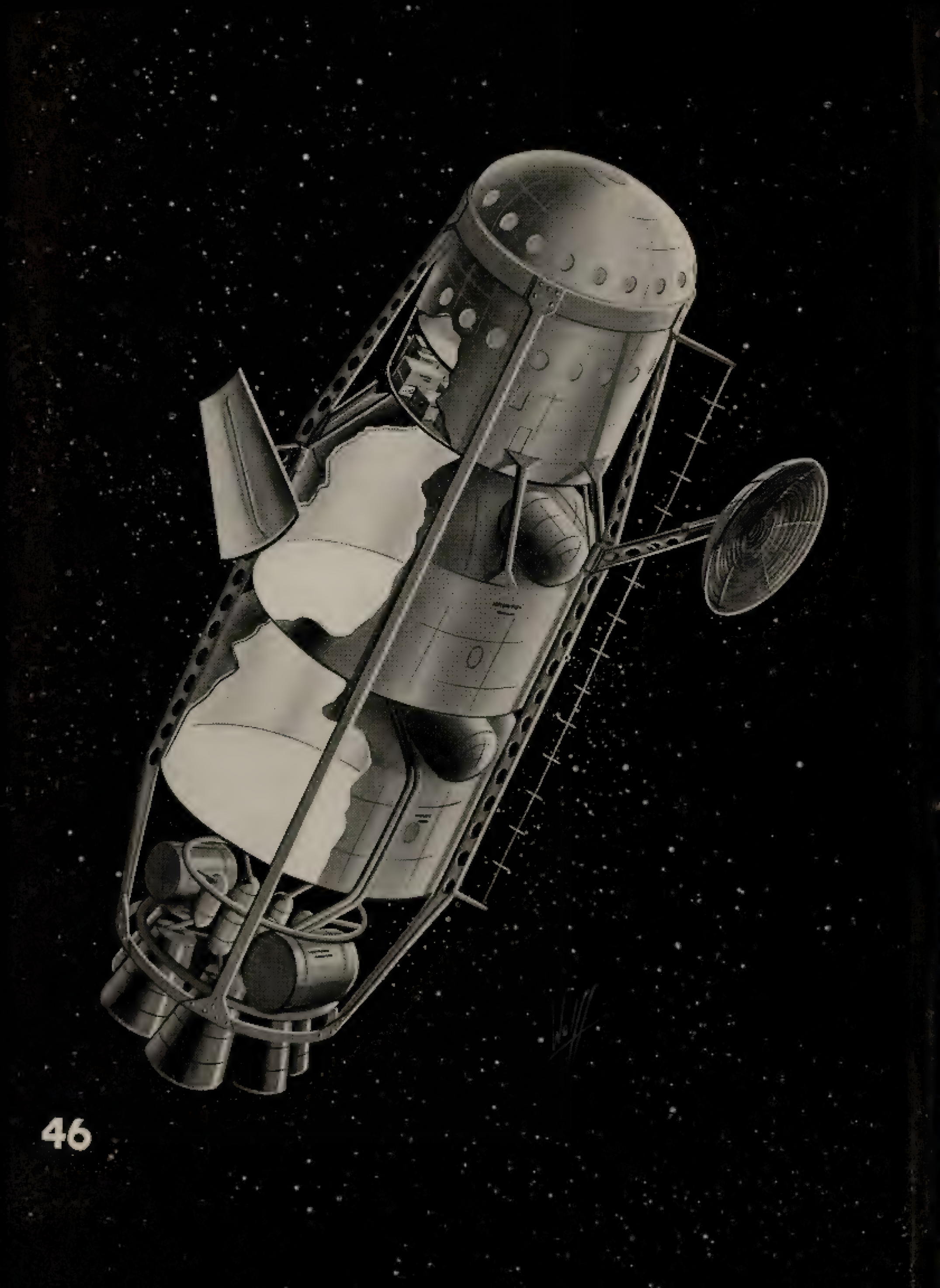
Captions continued on page 117

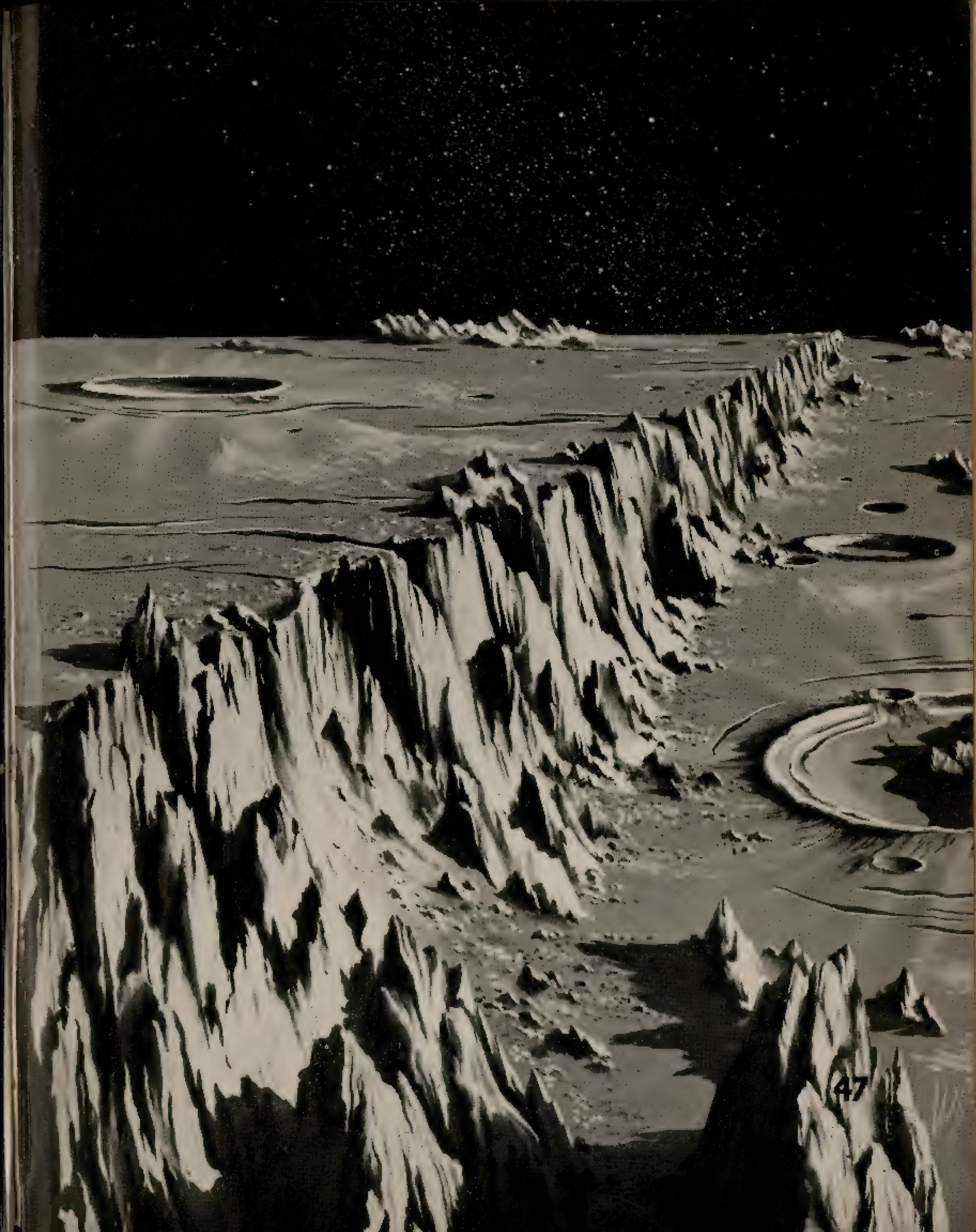

E-4


B-19


A-1


A-4





Fuelling the lunar survey space ship, spacemen couple long hose-lines together, from the space-ship tanker to the lunar survey vehicle. 41

Cargo transfer between the shuttle rockets making round trips from the earth to the satellite orbit and the satellite, will most likely be accomplished with the use of special "space taxis." These circular cargo and personnel carriers, used only in space, are equipped with pressurized cabins and cargo holds and a small reaction motor for propulsion and manœuvring in space. 42

In any military attempt to wreck or destroy a space satellite orbiting about the earth, the aggressor's moves are immeasurably aided by the fact that the satellite follows an absolutely precise orbit of specific height and velocity that cannot be altered. The attacker's objective, stated in the simplest terms, is to intersect that orbit so that a guided missile can arrive in the orbit simultaneously with the satellite. 43

The results of a missile strike against the space satellite. The first wave of small rocket weapons as it reaches the satellite's position in the orbit. In this illustration direct contact is required to detonate the explosive charge in the rocket; proximity fuse-triggered weapons could be used as well. Since several more waves of missiles will be fired immediately afterwards, the attacking missile may be assured of several direct hits against the space station. 44

As the first lunar survey vehicle circles the moon, spacesuited crew members push themselves away from their vessel to take historic motion pictures of the desolate world "below" them. 45

A cutaway of the lunar survey vehicle, as it may be constructed. The vessel is assembled in space with the parts cannibalized from a shuttle rocket especially constructed for this purpose. The fuel tanks are assembled from the curved metal plates of the space ship, as is the pressurized crew compartment. Steel beams for structural rigidity are taken from the space-ship frame; motor sections and auxiliary units and tubing are stripped from the shuttle rocket. 46

One of the outstanding features of the moon that will be closely investigated by expeditionary scientific forces that will explore earth's satellite. The Straight Wall, a natural fault of the lunar surface that runs more than 60 miles in length. Clearly seen on photographs of the moon, the Wall drops 300 feet from the edge to the surface below. 47

An exploratory space ship on its way from the satellite orbit to the distant moon, shown eclipsing the sun. 48

will serve to maintain structural rigidity and prevent possible collapse. Since every beam, girder, and metal plate used in assembly will be marked in colours and by number, workmen will piece these units together like a giant jigsaw puzzle, securing each section to the other until the skeleton is completed.

When the inner inflatable section is assembled inside the skeleton ring and inflated into its permanent position, a layer of metal will be fastened over the nylon-plastic as a shield against penetration by meteors. Over this inner layer there is affixed another steel layer to act as a buffer against the superfast tiny particles. Inside the satellite the metal decks are assembled and secured in place. Hatchways are installed to divide the entire ring into compartments. Equipment and machinery are installed, electric connections are made, plumbing pipelines are fitted, and ventilation machinery is connected with shafts through the satellite. Machine shops are set up and scientific equipment placed in position.

The operation continues on a 24-hour basis. Several ships are always in the orbit with the satellite as the framework is completed. Even as the tunnel running through the inner part of the ring from one wall to the other is assembled and the permanent entrance and exit airlock completed in the exact centre of the satellite, workmen in pressurized compartments are making the final adjustments and fittings to operational equipment.

Power for the satellite's machinery, communication equipment, and living facilities is supplied through a large solar mirror. This can be built as a circular unit of the same size as the satellite and can be mounted atop the station. Another arrangement would set the curved mirror atop the satellite on a movable hub. The mirror must face directly into the sun, except when it is in the earth's shadow, to receive the full effect of solar radiation. With the mirror as a fixed

unit atop the satellite, the entire station would have continually to be changing position. By mounting the power source on a revolving hub, photoelectric cells would permit the mirror continually to face the sun, making unnecessary movement of the station as a whole.

Before the satellite is ready for occupancy by its permanent garrison, rocket motors exactly opposite each other will be fired briefly, to spin the satellite. Rotating the satellite once every 12·3 seconds applies a centrifugal force of 1 g to the outer deck. One-third gravity will meet the satellite needs, however, and allow greater than ordinary freedom of movement; under these conditions, the station is rotated to complete a full turn every 22 seconds.

The return trip by shuttle rocket to the planet's surface will be a journey involving far greater tension than did the climb, during which the crew acted as passengers until the final power manœuvre was made to settle into the orbit. To return to earth the space ship must eliminate the momentum of more than 18,000 miles per hour achieved during the ascent, when climbing energy in the form of velocity was imparted to the ship. While the space ship orbited about the earth in a vacuum, that energy as velocity was unimportant, but in the return to earth the energy is manifested as heat when the speeding space ship strikes the atmosphere. To prevent the ship from burning up like a meteor, the energy release must be gradual.

When leaving the satellite's position in space, the pilot operates the gimbal-system gyroscopes to turn the ship around so that the rocket tubes point in the direction of the orbital movement. After a short blast of power to reduce the speed of the space ship, it begins to fall back to earth. Climbing at a height of more than 20 miles, the V-2 rocket tumbles end over end if unbalanced; the atmosphere above that height is so tenuous that it cannot affect the movement of the

rocket. The velocity of the V-2, however, is less than 4,000 miles per hour; the returning space ship is moving at a speed of more than 18,000 miles per hour.

When the space ship passes through the extreme upper atmosphere and descends to a height of 50 miles, it is still moving at a velocity of more than 14,000 miles per hour. At an altitude of 50 miles, that velocity through the tenuous atmosphere is great enough to affect the ship's movement. By pushing the control stick all the way forward so that the elevators keep the speeding vessel moving downwards, the pilot reduces altitude and lets air friction further slow the ship. A loss in velocity of 1,000 miles per hour requires a forward movement of some 10,000 miles in the upper atmosphere. This is sufficiently slow to permit a further descent to even lower heights, where the atmosphere becomes "thick" enough to slow the ship to a forward velocity of 6,000 miles per hour within a distance of 3,000 miles.

Descending in this fashion through the atmosphere to lose the energy of its momentum through dissipation of heat, the space ship's outer skin is soon glowing a deep copper-red. Skin temperatures, as calculated by von Braun, will run as high as 1,300° Fahrenheit. Heat-resistant steels can withstand such temperatures without difficulty. Inside the sealed cabin the crew is protected by refrigeration equipment, glass-wool insulation, and other heat-resisting aids. The forward pilot's canopy and the navigator's bubble and portholes are double-layered sandwiched glass or other transparent material between which an invisible coolant is circulated to prevent their melting.

Fifteen miles above the earth, the space ship is flying like any supersonic, swept-wing aeroplane under power-off flight conditions. Before long it will slow down to the speed of sound. Unless the aero-

dynamic design permits an easy flow through Mach 1. speeds, the ship could be damaged or even broken up.

Aviation engineers are turning in stronger numbers to the delta-wing design as the solution to the myriad problems of supersonic flight for both small fighters and bombers of B-29 size. Not only does the sharp sweep-back of the delta allow smooth airflow at the height of turbulence when at Mach 1. speeds, but the considerable wing area, with spoilers and leading-edge slots and flaps, permits high lift for slow landing speeds and good slow-speed handling characteristics.

Finally the ship approaches its landing-base. Chase fighters, speedy jets which accompany the space ship in its approach and landing-run to assist the pilot, are already in the air following and leading the great ship. At a speed comparable to present transport and bomber aircraft, the still-glowing space ship drops to the ground.

More than 1,000 miles above, invisible to the naked eye except briefly at dawn and dusk, a giant station is whirling about the planet. Man has achieved the first of many steps in his struggle to conquer space.

6

Earth below

Suspended more than 1,000 miles in space, the satellite garrison will be treated to an awesome spectacle of the earth below. Seemingly the great globe will be "spinning" at a great speed, making a complete turn every two hours. All about the station space will be Stygian blackness, pierced by gleaming stars. Paradoxically, to the unprotected eye the blinding light of the sun will be almost as bright as the heart of an atomic fireball. Exposed to the nearby star, the station will float in a brilliant glare; its surface heat would be many hundreds of degrees except for the light-reflecting materials which cover the steel skin. In shadow, the temperature will register as hundreds of degrees below zero.

The earth will be a shimmering globe framed in blackness. Satellite viewers will be unable to look with the naked eye at the polar icecaps, and even large cloud formations will reflect sunlight with painful brilliance. Against the predominant blue of the vast ocean areas, continents and islands will stand out in stark relief as green, grey, black, and brown. As the night-darkened planet areas come into view, glimmering pools of light will mark the larger cities. The garrison will watch the deep red of dawn and the purple of night sweep like an endless tidal wave across the surface.

Mere sight-seeing, however, is not the purpose of the satellite

garrison. Survival in space, even within the protecting steel walls of the space-station, is an endless battle against an uncompromising alien environment. Even survival is incidental; man is in space to expand his scientific understanding of his world and the physical universe and to advance into the solar system. While the satellite's scientific complement, comprised of "permanent-duty" personnel and an ever-changing number of scientists and engineers who make round-trip shuttle runs from the earth, fulfils its research mission, the military garrison operates and maintains the space station.

Although the satellite is weightless in free fall, centrifugal force creates an artificial gravity. The preceding chapter briefly showed that the spinning satellite, making a full revolution every 22 seconds, established a gravity one-third of normal. Effective as this arrangement may be, the spinning motion is an engineer's nightmare. Since the satellite is not an object internally at rest, but one which involves the movement of men, equipment, liquids, and machinery, the garrison engineers must be constantly alert for a shift in balance of weight which, if severe enough, could overstress the fragile construction members and break up the station.

Engineers are assigned to maintain proper weight distribution and balance at all times. Much of this work is simplified by knowing that large numbers of the garrison crew will remain in the general vicinity of their assigned stations at certain times. When significant changes in weight distribution become necessary, as during relief of garrison crew members by personnel from earth or the delivery of cargo from earth, the engineers will control the disposition of all equipment and personnel.

In space these objects are weightless. Within the spinning satellite centrifugal force imparts to them an artificial "weight." Objects at the station's outer deck farthest from the centre airlock will be

the heaviest. As a man moves in the tunnel towards the centre of the satellite and is spun about less rapidly, he weighs progressively less until in the airlock itself he is weightless.

A major weight change occurring suddenly at any part of the station will unbalance it and may cause it to wobble or oscillate. Although constructed of metal, the space station is a comparatively weak structure. Any sharp deviation from normal strain will tend to part the steel plates and beams, and possibly wreck the satellite.

To compensate for inevitable changes in weight distribution, liquid-ballast tanks run the circular length of the station. Sensitive instruments capable of registering weight changes maintain a constant "fluid weight balance." For example, if several men were to move from the east side of the station through the centre tunnel to the west side, resulting in a sudden change in the distribution of weight, liquid ballast would automatically flow into tanks adjacent to the compartments just vacated. Enough liquid ballast is transferred to equalize the weight shift, and the satellite's equilibrium remains basically static.

Miles of wire and electronic relays wind their way throughout the station to operate uninterruptedly the hundreds of instruments, generators, machines, and automatic safety devices. Power must be supplied constantly to air-conditioning, communications, heating, cooking, refrigeration, weight control, pump systems, pressurization units, emergency alarms, lighting, water-recovery apparatus, fuel tanks, and other equipment. Normally that power source would be a major engineering obstacle to maintaining the outpost in space.

Ninety-three million miles away, however, a gargantuan atomic furnace throws out incredible amounts of energy in the form of heat. By trapping some of this heat energy through giant mirrors affixed

to the station, the power requirements of the satellite's multiple equipment are more than met.

Scientists have long experimented with solar mirrors to harness the sun's energy as a source of machine power. There have been a number of interesting and usually very costly solar ovens which scientists hoped could tap solar energy. Drawing upon the sun with its surface temperature of 10,000° Fahrenheit, these ovens have proved valuable for experimental purposes, but their high cost has balked commercial exploitation. Generally the equipment has been too inefficient in power output to justify the expense.

Most promising of these solar power plants is the great furnace now being tested in the French Pyrenees as a means of alleviating France's power shortages. Designed by the solar power engineer Felix Trombe, the mirrors consist of two large reflectors mounted atop an ancient fortress. A flat 43-by-34-foot mosaic of 516 plate-glass mirrors, constantly deflecting the sun's rays to a fixed mirror 80 feet away, follows the sun in its path across the sky. Three thousand five hundred pieces of glass make up the 31-foot-high parabolic-shell receiving mirror, which in turn reflects the sun's rays to an oven set between the two great reflectors. Its curves focus the heat rays and create oven temperatures up to 5,400° Fahrenheit.

The energy output of the French solar oven makes it the world's most powerful. Seventy-five kilowatts of heat power, enough to melt more than 100 pounds of iron every hour, are generated by the furnace. It operates on an average of 250 days a year in sunny Montlous; if the mirror were set up in an area such as Algeria, where greater and more consistent heat is available, its efficiency would increase substantially.

In space the heat energy received from the sun is far greater

than that received on the earth's surface, where the heat rays are substantially filtered out by the dense atmospheric blanket. As compared with the 75 kilowatts of energy generated by the Trombe mirror, the satellite solar furnace can provide an estimated output of between 400 and 600 kilowatts of energy.

Various solar-furnace designs have been proposed for use on space satellites. Von Braun envisions a highly polished metal trough running the circular length of the station. In this design, photo-electric cells and automatic motors tilt the entire satellite so that the condensing mirror always faces the sun. A more efficient design with a mirror mounted on movable facets obviates the necessity for moving the entire satellite.

Heat rays from the sun are focused on a mercury-filled metal pipe running the length of the mirror. Heated to vapour, the gaseous mercury is transferred to a power room to drive a turbogenerator producing electrical power. After passing through the turbine the mercury vapour is circulated through cooling pipes in the satellite's shadow. This dissipates the heat into space and returns the now-liquid mercury to the boiler pipes, to renew the cycle.

A popular misconception holds that temperature in space is "absolute zero," or $-273°$ Centigrade. Actually, since space is a vacuum and is "nothing," it cannot possess temperature. Objects in space will have temperatures depending upon their proximity or exposure to a heat source, such as the sun, and their colour. Objects of light colour reflect more light and heat than do those of dark colour; the darker the substance in space, within a distance of the sun to be affected by that body, the hotter it will be.

Equipment exposed to the direct rays of the sun for long periods of time will be coated with light or dark colours, depending upon the temperatures desired. Since surface colour greatly determines temperature, satellite engineers are provided with ready-made temperature regulators. Along the surface of the station will be special metal grids, with opposite sides of black and white. The temperatures generated by these grids as they absorb solar heat will be measured by automatic thermostats. Set at the desired temperature, these will regulate the station's heat.

For example, if the temperature were 50°, and 65° was desired, the thermostats would be set at the latter figure. Automatic controls would rotate the outside grids to expose the black surface to the sun, thus increasing the heat they absorb and radiate locally. Temperature in the satellite would rise until it had reached 65°, when the automatic controls would again rotate the grids to expose less of the black surface. Connecting the electrically controlled grids and the automatic thermostat to the satellite's air-conditioning system will permanently regulate the temperature.

Except for specific use, viewing ports will be covered with outer metal shields. The ultra-violet radiation constantly expelled by the sun in the form of energy explosions is strong enough to discolour and reduce the transparency of glass and plastic. In addition to this, exposed ports would permit the entry of sunlight directly into the satellite, causing an undesired increase of heat. A steady view of the sun, even through tinted glass ports, can cause discomfort and possibly damaging after-effects to the eye. The discolouring properties of this ultra-violet radiation may require replacement of glass and plastic exposed for long periods of time to the sun's direct rays as a regular maintenance procedure. Spacesuit visors, darkly tinted to protect the wearer's eyes, may become so muddied as to impair visibility. The shuttle rocket's large, exposed pilot canopy and navigator's bubble may be replaced regularly for the same reason.

Usually there will be at least one shuttle rocket orbiting with

the satellite about the earth, transferring personnel and delivering food, mail, and equipment. Cargo will be transferred between the space station and the space ship by small rocket-powered cargo carriers. These cylindrical carriers will load cargo from the shuttle rocket and move to the satellite hub with brief bursts of power.

The satellite hub, with its airlock and cargo-receiving facilities, is so constructed that the entry tube for the space taxi is rotated against the spinning motion of the station. Otherwise, the airlock entry tube would turn with the satellite, making a connection difficult if not altogether impossible. During cargo-transfer operations, electric motors spin the airlock in a direction opposite to the satellite's movement so that it remains stationary. The space taxi is then manœuvred into the tube, and the forward part of the cylinder sealed tight against the tube interior. Cargo is then transferred into the satellite's receiving hatch. Once the transfer operation is completed, the motion of the airlock and cargo tube opposite to that of the satellite is slowly reduced until it is once again turning uniformly with the permanent satellite sections.

Space meteors, which will be encountered by the billions every year, present a constant hazard to the satellite and its personnel. Contrary to the popular concept, most meteors are not great boulders of iron and rock hurtling out of space to crash with devastating force on the earth. Most meteor particles are actually no larger than dust motes. A meteor even the size of a pea or bullet is an unusually large piece of interplanetary debris, and the real giants are sufficiently rare to arouse international interest. The largest meteorite on exhibition weighs 36 tons. Originally the scarred and pitted celestial boulder weighed many tons more, but its flaming passage through the atmosphere reduced the over-all mass and size considerably. A satellite struck with a meteor of this size would be smashed

and exploded into scattering wreckage instantly. Fortunately the chance that any objects the size of the satellite, which is infinitesimal in the vastness of the solar system, will be struck by such a visitor from space is so remote that it need not enter into our calculations.

The more common meteoric dustlike particles will constantly shower down upon the satellite with great force and velocity. These approach the earth at a minimum velocity of six miles per second; meteor trackings have recorded frequent impacts with atmosphere at velocities of 45 miles per second, or 162,000 miles per hour. The rarer highest-speed meteors approach at the rate of 100 miles per second, or 360,000 miles per hour!

Since even "slow" meteoric particles will strike the satellite's outer skin at a speed of more than 22,000 miles per hour, the station must be shielded to prevent penetration and subsequent explosive rupture of its compartments. Astronomers believe that one pea-sized meteor may collide with a station once every 30 days. A meteor the size of a man's fist, striking the satellite at a speed upwards of 100,000 miles per hour, would tear through steel as if it were thin tissue paper. Protective measures against this rare occurrence could be provided through compartmentation, resembling that found on naval vessels. If the satellite skin were ruptured by the explosive meteor impact, only the penetrated compartment would lose its atmosphere into space. Automatic alarms, set off by a rapid drop in air pressure in any part of the station, would alert emergency repair crews and automatically close all hatchways leading into other compartments.

Thus would the satellite survive the impact of even a large meteor which, because of its velocity, speedily loses its penetrative powers. The terrific impact would blast the meteor into dust almost instantly,

although its great speed of approach would unavoidably enable it to inflict considerable damage.

The more pressing problem is protection against constant impact with the average meteor particles. These minute visitors from space are blasted into dust within an extremely short distance, measured in small fractions of an inch, after striking or penetrating a plate of steel. Ordinarily the satellite's outer skin will be continually bombarded by these particles; a permanent means of protection, then, may be established by constructing around the entire station an outer steel "meteor bumper." Meteors smashing into the bumper several inches beyond the main structural covering of the satellite, will be blown into dust, depriving them of all or most of their penetrating power. Atmospheric pressure maintained between the satellite outer shell and the bumper provides an additional barrier against penetration of a meteor into the station.

Even if the meteor were large enough to pierce both the bumper and satellite shell, it would still face the nylon-plastic inner wall which could be constructed in much the same fashion as wartime self-sealing fuel tanks. While these tanks were on many occasions penetrated by bullets which ripped completely through the tank, the rubberized edges immediately flowed together to seal the holes. This same principle is employed in safety tires for automobiles; nails penetrating the tire do not create a blow-out, since the rubberized qualities of the tire allow a special chemical gum to flow around and seal the puncture.

A self-sealing inner wall further reduces the danger of meteor penetration and subsequent explosive decompression. It is, of course, possible that meteors will overcome these three defences and create a leak in a satellite compartment. If so, automatic controls registering

drops in air pressure will seal the compartment or compartments affected. Individuals in that compartment would be compelled to act quickly to save their lives and plug the leak temporarily until full repairs could be made.

The automatic alarms immediately release emergency air into the struck compartment together with a harmless, brightly coloured gas. Any leak in the inner wall would draw the coloured gas towards the rupture, identifying the source of danger. Crewmen, given life-saving emergency air, then have time to slap an emergency patch over the leak. A combination of an adhesive substance on the patch and air pressure will serve to keep it in place until major repairs are effected.

The application of centrifugal force to produce simulated gravity eliminates a serious problem of air, water vapour, and gaseous control within the satellite. Under conditions of zero gravity, hot and cold air will not separate as they normally do on the earth, where the warmer air rises to the top of a room and the cold air sinks. The air exhaled by a crew will not move very far away from each man, and would soon fill a cabin with waste air products and carbon dioxide in sufficient concentration to create a severe physiological problem.

In addition, each man loses approximately three pounds of water a day through exhalation, perspiration, and waste discharge. A space-ship cabin without a continually operating system of fan dehumidifiers would soon be filled with concentrated mist. Both a chemical process and a mechanical method would be required to remove the excess carbon dioxide and moisture from the air and cleanse it for repeated use. Rebreathing air is not unusual; the process of reclaiming expelled waste gases has been tested in submarines

for many years. Unlike a submarine, however, the space station cannot simply surface to an inexhaustible supply of breathable air should the reclaiming apparatus misfunction.

The rotating satellite eliminates much of this problem through simulated gravity, except in the centre hub station where a forced-draught system disposes of the problem of exhaled mist and dangerous gases. Not so simple is the problem created by the shuttle rockets and the vehicles which will subsequently journey to the moon and planets. Without centrifugal force substituting for gravity, space ships must be fully equipped to meet and solve these pressing problems. Every man within the satellite requires at least three pounds of oxygen, helium, and the other chemical components which constitute his breathable atmosphere each day. For a 95-man garrison, the satellite must be provided with 25,650 pounds of breathable atmosphere for every three-month period. One shuttle cargo rocket of the von Braun design could transport to the station in a single trip enough atmosphere for just about this period of time, at an estimated cost of $500,000 and nearly 6,000 tons of chemical propellants. The metal tanks containing air under high pressure constitute much of the cargo weight transported to the station. Over a period of several years this entails a cost of many millions of dollars merely to provide the basic minimum of breathable air for a garrison of moderate size. The concept of an additional source of atmosphere through the re-use of exhaled air is more than nullified by expected accidents, meteor penetration, and air supply for spacesuits and mechanical apparatus.

One solution to the problem of air supply may be to convert several satellite compartments into a "greenhouse in space." Normally this suggestion, since it entails devoting a specific amount of cubic space to the growing and maintenance of plants, would be rejected

on the ground that the area thus used is far more valuable for scientific instruments and equipment. A station in space, however, representing as it does many billions of dollars, years of concerted effort, and the labour of an army of tens of thousands of people, is designed to perform its intended mission for many decades after it is established. Over this period the cost of air supply from the earth may eventually exceed the original price of satellite construction and entail the expenditure of thousands of tons of fuel. Much of the satellite's atmosphere requirements can be provided through special types of plants; vegetation absorbs expelled carbon dioxide and waste gases and exudes fresh life-giving oxygen in return. Some plants are better suited to this purpose than others, and the development of specific high-oxygen-producing plants may eventually provide the major source of this vital gas for the station.

Eleven square feet of leaf from the pumpkin vine, for example, provide sufficient oxygen to meet the survival needs of the average man at rest. Such oxygen-producing plants as *chlorella algae*, when grown in shallow water and illuminated by strong natural or artificial sunlight, produce up to 50 times their own volume in oxygen per hour. The more efficient plants of this nature can be adapted for use within the satellite; the accelerated growth which occurs under conditions of one-third gravity or less indicates that the efficiency of even the *chlorella algae* can be exceeded as an oxygen source. The "green thumb" may prove as important in space as on the earth!

The artificial gravity induced by the satellite's rotational movement eliminates many of the problems of food and liquid nourishment present in a vessel in space under weightless conditions. With the exception of the lesser "downward" force along the satellite decks, the preparation and consumption of both foods and liquids will be basically the same as on any tightly compartmented vehicle.

Foods will be selected on the basis of maximum nourishment values, as well as consideration for bulk. Each man will require several pounds of food each day, as well as liquids and essential dietary supplements in the form of vitamin pills.

The maximum cargo load of the shuttle rocket is 40 tons, but many millions of tons of chemical propellants and millions of dollars' worth of food will be required to maintain the satellite garrison. Food substances dispatched to the station will be frozen, packaged, and dehydrated in order to reduce as much as possible the physical space required in the shuttle rocket used for food transportation. Fresh meats prepared in electronic cookers, and other foods prepared with the best scientific kitchen equipment, will assist greatly in reducing the logistical problem. The experience gained from many years of food preparation aboard naval vessels, such as destroyers and submarines which remain at sea and away from a supply base for long periods of time, and packaged meals served aboard commercial airliners, will set the pace for satellite provisions.

The disposal of waste products would constitute a major problem were it not for the fact that the shuttle rockets returning to earth will have only partially filled or empty cargo holds. Waste materials collected from the daily living and working routine of the satellite garrison will be packaged in lightweight plastic containers and, when a shuttle rocket returns to the earth, sent back to be destroyed. Waste matter cannot be jettisoned into space; within a short period of time the space about the satellite would be cluttered with swarms of garbage and other matter orbiting about the station like thousands of miniature moons. They could be sent into the sun or into outer space in expendable rockets, but that would entail the costly transportation of expensive rockets and fuels from the earth. The added

weight of the waste matter will not materially increase the landing speed of the returning shuttle space ship.

The basic goals of the satellite project are meteorological and geophysical observations of the earth, astronomical studies and observation, and the first surveys and exploration of the moon and later the planets. This will occupy the greater part of the satellite garrison's energy. Photographic surveys of the earth from this lofty vantage point will finally produce an absolutely accurate international scale map. Special instruments developed for this project will permit accurate charting of many mountainous areas of which little is known at present. Meteorological studies will produce the most efficient weather predictions, for satellite observers will be in a position to note the birth of hurricanes, typhoons, and other destructive storms. Notification to ships, aircraft, and land areas in the path of these rampaging forces of nature will serve immeasurably to reduce the annual loss of many thousands of lives and property damage costing untold millions of dollars. Meteorologists will be able carefully to chart the weather patterns of the upper atmosphere and their relationship to weather changes nearer the surface. A whole new vista of meteorological science can be opened up through scientific observations from space.

If, as von Braun claims, satellite observations will permit a study of the earth with special optical instruments which reproduce seeing range of an observer only 4,000 feet above the surface, many lives lost annually in shipwrecks and planes can be saved. Planes and ships sent out on search missions for aircraft downed at sea and for the crews of foundered vessels can be aided or reduced in number by the all-seeing satellite which will be able to pinpoint the scenes of such disasters for rescue forces.

In the interests of pure research, perhaps none of the space station's work will be more important than its astronomical studies. Even the design and construction of an observatory in empty space are a challenge to astronomers, who have always been plagued with the shimmering obstacle of an atmosphere saturated with water vapour, dust, clouds, and other elements restricting their observations. The exact position of the observatory in relationship to the satellite must first be determined. Placing the observatory in such a position that it describes a circular orbit about the station as a secondary satellite allows the station to come within the line of sight of the observatory telescope too often and limits its effectiveness. The best position seems to be a location ahead of or behind the satellite, in the latter's precise orbit.

The problems of orienting the observatory, maintaining its position in relation to its specific photographic assignment, will affect the final technological design. The rapid temperature changes produced when the observatory is directly in line with the sun or shielded by the earth dictate efficient shielding of the observatory's delicate instruments. While the technological problems of constructing the observatory in space are many, the unique environment also simplifies the builders' task. Electronic equipment which must operate on earth with a complicated arrangement of vacuum seals, a considerable problem of design, construction, and maintenance in the gaseous atmosphere, will function perfectly and with little difficulty in the vacuum of space. It will be possible to construct 100-inch- and 200-inch-diameter reflecting mirrors, since the metallic reflecting surface can be applied easily in a vacuum. Because of the precise direction controls required for most astronomical photograph projects, the observatory will be operated completely by automatic and remote computers; this will include the operation of

camera shutters and other devices. The changing of film plates, camera settings, and exposures can best be performed by remote control; the only direct manual operations would involve the replacement of film plates and maintenance duties.

The spectroscopic methods employed to study far ultra-violet, X- and gamma-rays will be adaptations of present laboratory techniques. Many of the electronic, photoelectric, and other technical problems incidental to the use of spectroscopic equipment will be simplified by the ability to work in the universal vacuum surrounding the station. Radio astronomy research will be greatly expanded by construction of very large radio antennae about the satellite, and this branch of research will be greatly facilitated by existence of the equipment above ionospheric interference. Electromagnetic spectrum studies of ultra-violet, X- and gamma-ray regions in radio astronomy will be possible for the first time, since, according to Dr. Fred L. Whipple of the Harvard College Observatory, these are completely invisible from the earth's surface.

Problems of solar structure and activity will be met with specialized equipment of several varieties, each designed to attack a specific phase of solar phenomena. Particular interest will be paid to the direct measurement of solar corpuscular radiation, solar flares and coronas, the far ultra-violet and X-ray spectra and their variations. Science may have determined the question of the source of cosmic rays by the time the satellite becomes a reality; even if this is accomplished, however, much additional work bearing on the subject can be performed only from the vantage in space.

The high resolving power of large telescopes in space will permit a thorough study of the complete chemical composition of all planetary atmospheres, since the far ultra-violet light will reveal the presence of molecules and atoms which do not absorb light in the

photographic regions. Surface conditions will be revealed to the in-space telescopes with a resolving power of approximately ten miles possible in studies of Mars with a 100-inch telescope.

Of particular interest to astronomers are the nature, composition, and evolution of stars; the processes occurring in stellar atmospheres, particularly loss of material; circulation of great clouds of material about double-star systems; and possibly in some cases the accretion of matter by stars from the interstellar medium. It will be possible to obtain clear insight as to the spectacular novae, the supernovae, the peculiar variable stars, the giants, and the extremely hot stars, as well as the enigmatic white dwarfs of extremely high densities.

Only by establishing the astronomical observatory beyond the earth's atmosphere can astronomers and scientists determine the composition of the interstellar medium. Many of the great gas and dust clouds scattered throughout the Milky Way galaxy are actually cosmic incubators in which new stars are constantly being created. Astronomers already know that the stars they have observed through the restrictions of the atmosphere are ancient, some more than three thousand million years old. Comparative youngsters, perhaps in existence only 100,000 years, have also been noted.

These old and young stars are fundamentally different in composition. Astronomers believe that changes in the nature of the interstellar medium have wrought evolutionary alterations in the make-up of newer stars. These changes may have occurred by selective accumulation of stars from dust, rather than from interstellar gas clouds, or possibly by the addition of heavier elements to the interstellar medium by the explosions of other stars. It is possible, as has been suggested by Fred Hoyle, that matter is actually being created at the present time.

Finally, we shall approach the most fascinating of all the scientific work arising from the great project of establishing the station in space: outward journeys to the moon and the first exploration of another world by man.

No Invulnerability in Space

In the form of the space satellite the United States has been offered an "invulnerable weapon," with which it can "assure" world peace. The weapon offered is the manned space satellite, with which we are now familiar. The gist of the argument, supported most strongly by Wernher von Braun, is that the space satellite, whirling in its orbit more than 1,000 miles above the earth, is the ideal bombing platform, the perfect control point for guided missiles bearing the atom bomb. Protagonists of this so-called invincible weapon claim that satellite observers can make constant, clear, and close observations of terrestrial activities; that they will be able to notice an attack by any nation before it can gather momentum; and that the satellite can launch missiles from its orbit against surface targets with absolute accuracy and thus end the war before it really starts.

This paints a very pretty picture of a peaceful and prosperous future. Unfortunately it is little more than a theory with little enduring value. Its success is based upon a number of premises, none of which has been found capable of withstanding serious analysis.

If we were to assume that strides in missile control were so great that the proposed orbit-to-earth weapons were guaranteed a fair margin of success by 1962, then the establishment of a bombing platform in space would be a complete waste of effort. Missiles with such precise control as is demanded by the space-satellite arrangement could do their job just as well *on* the earth. Why haul the

missiles at great expense in material and money into space, only to throw them back eventually, when they can be launched from surface positions just as effectively?

To counter the claim that the satellite is an invulnerable bombing platform, one has only to enquire when a missile can be fired from the earth to intercept the satellite in its orbit and destroy it with either simple explosives or an atomic bomb. It would seem logical that if one half of the world's civilization devotes all its resources to setting up the satellite in space, then the other half could devote its energy to destruction of that satellite with an excellent possibility of success.

Von Braun's claims enjoy the support of a small number of allied engineers. Apparently, however, the majority of missile technicians and scientists strongly disagree with von Braun's trend of thought. Their criticisms are based not only on the technical faults underlying the claim for invulnerability. There is a matter of psychology to be considered. The critics of the bombing platform say that concentration on a proposal so full of error will do more harm than good. They point out that the entire affair resembles a swindle because space-travel enthusiasts are offering hopes for permanent peace through a plan which cannot possibly hope to achieve success, simply to further the development of their objective.

Perhaps no writer has better expressed this collective opinion than did Eric Nicol of the Winnipeg *Tribune*. In his column of May 10, 1951, Nicol referred to the readers of *Collier's* magazine, which had publicized von Braun's space bombing-platform ideas:

"A lot of them are going to be susceptible enough to swallow unchewed your editorial of war gadget-mongering in the name of peace. That's bad . . . It is grotesque foolishness of the most dangerous sort to suggest that a space station riding herd on the world

with a load of atomic bombs would guarantee world peace . . . The space-dunking doughnut envisioned by Dr. von Braun would be a guarantee of world violence. As an instrument of policy it would mean that might was right because so was Uncle Sam. Always. And as an instrument for peace it would be as ineffectual as exclusive possession of the atomic bomb was to the United States—breeding nothing but fear and the determination to have the same weapon."

The satellite will undoubtedly have a bewildering variety of uses. These are both military and scientific, and most probably a combination of the two. But the insistence upon a nationally sponsored programme to establish a space satellite intended for world domination, based upon theoretical considerations which are open to grave doubts, can do the future of space travel more harm than good.

7

Expedition across Space

Almost 60 per cent of the total moon's surface will be photographed from the satellite's astronomical observatory. The detailed topographical map thus obtained will provide scientists with a complete picture of the height and size of mountain ranges, craters, rays, surface cracks and rills, depressions, plateaux, and cliffs. From this essential data the celestial cartographers will select the most suitable landing-site for the first space ships which will descend to this alien and hostile world.

Before the first expeditionary space ship departs, a smaller survey vehicle may be sent across space to circle the moon and record surface conditions on the side which faces perpetually away from the earth. There is every reason to believe that the never-seen portion of the lunar surface, about 40 per cent of the total area, does not differ greatly from the visible section. We will not know with certainty what lies on the other side of the moon until man actually records these features.

We can see more than half of the lunar surface because the moon moves in an elliptical rather than a circular orbit about the earth. This erratic swing sends the little world out to a distance of as much as 252,710 miles from the earth and brings it as close as

216,240 miles. Small in comparison with the earth's considerable surface, the moon's area of 14,650,000 square miles is nevertheless extensive. Although the moon's diameter of 2,158 miles is only one-fourth that of the earth and is less than the coast-to-coast distance across the United States, this territory is almost as great as the combined areas of the North and South American continents. Exploration of this barren, airless, and hostile world will be inconceivably more difficult than a comparable exploration of a similar area on the earth, since transportation by air or surface craft will not be feasible.

The survey space ship dispatched from the satellite will provide scientists with more accurate and detailed information than can be obtained even by the orbiting observatory. The cost of the entire expedition will represent only a small fraction of the expense involved in the satellite project, since the ungainly space ship with its essential members bolted and welded together along steel beams will be constructed in the satellite orbit from the parts of one of the shuttle rockets.

One such rocket, carrying in its cargo hold the essential construction items not provided in its own frame and sections, is disassembled in the satellite orbit and then put together to make up the survey space ship. The rocket-motor section, with accompanying hydrogen-peroxide motor and fuel tanks, fuel lines, and accessories, will be bolted to a circular or squared steel-beam frame. From the wings and fuselage sections come the curved and flat steel panels which will form the outer shell for the two fuel tanks. Deflatable nylon-plastic fuel bags are ferried to the orbit and inflated to fit snugly within the steel enclosures, to which they are fastened securely. The fuel lines are then assembled in place, and auxiliary power equipment and electrical connections made. Forward of the fuel tanks, the pressurized compartment for scientific personnel is bolted

to the leading fuel tank, to the steel beams which run parallel to the motor sections, and to the fuel tanks.

The pressurized living compartment is composed of several sections including the living quarters which, although cramped, are sufficiently large to embody all basic needs for a comfortable existence. These quarters will be pressurized and will be furnished with air-conditioning and temperature control, a water-recovery system, toilet facilities, and other essential services. A small airlock leads out of the space ship from this pressurized section; this will be used when the vehicle approaches and circles the moon. Located in the pressurized section, but separate from the living quarters, a cargo hold accommodates food and liquid supplies for the ten-day journey, as well as scientific equipment, emergency air tanks, and other necessities. Instrument and communications equipment for the survey vehicle is provided by the dismantled third-stage shuttle rocket; special instruments required for scientific work are brought into the satellite orbit as cargo.

The space station is protected against meteor penetration by the outer bumper and by the "third-defence" self-sealing inner wall of the station. The pressurized compartment and fuel tanks of the survey vehicle are shielded in the same fashion.

Power needs for living facilities and for operation of scientific and communications equipment are supplied by a small solar mirror extending from the side of the space ship. During the period of free fall from the satellite in the elliptical orbit around the moon and return, gyroscopic controls and photoelectric cells keep the vessel so oriented in space that the mirror constantly faces sunward. A large radar "dish" antenna jutting away from the space ship is used for beamed communications, and scientific communications are facilitated by aerials strung along the steel-beam framework.

The same basic rocket-power control system employed in the shuttle rocket when it is above the atmosphere is adapted for use in the survey ship. The pilot controls which operate the external control surfaces when the shuttle rocket performs as an aeroplane are, of course, not utilized in space.

At blast-off time the flywheel gyroscope controls turn the vessel so that it is perfectly aligned with the satellite's orbit; the forward part of the survey ship points in the direction in which the space satellite moves. The navigator uses the fixed stars for celestial reference points and the nose of the space ship for a horizon, and operates the flywheels to turn the vessel to the required position. At this precise moment the rocket motors are turned on at full power, and within two minutes add a further speed of 6,340 miles per hour to the space ship's orbital velocity of 15,840 miles per hour. The total velocity of 22,100 miles per hour is sufficient to enable the space ship to continue on to the moon in free fall without further impetus. For the first two minutes of flight the crew are pressed back into acceleration couches; thereafter they suddenly become weightless once more.

During the remainder of the satellite-to-moon trip the survey ship slowly loses momentum as the earth's gravity reduces the initial velocity. It is moving fast enough, however, to reach the moon and coast beyond it before the combined gravitational pull of the moon and earth stop the outward movement and swing the ship around at the farthest point of the extended ellipse orbit. Five days after the vessel has left the satellite, it is 50 miles above the mystery side of the moon, circling that body in free fall. The scientific crew is hard at work taking motion pictures and still photographs. Thousands of feet of film are also exposed to picture the earth from the greatest distance man has yet travelled from his home planet.

Soon the ship has completed its free-fall orbit about the moon and swings back towards the distant earth. It begins to pick up speed until, as it nears the satellite's orbit, it is plunging back to earth at a rate of about 22,000 miles per hour. The navigator uses the flywheel controls to turn the ship round in space. Two minutes' full power, a reverse of the blast-off procedure, reduces the falling velocity by the same 6,340 miles per hour; now the survey space ship is again orbiting about the earth at the same height and velocity as the space satellite. The entire trip has been so carefully timed that when the ship decelerates to a speed of 15,840 miles per hour it will closely intersect the satellite's position.

The satellite sends out space taxis to meet the survey vessel and to transfer the scientific personnel and their precious film cargo. These then await a shuttle or transfer directly to the rocket which will return them to earth. Soon the spectacular motion-picture scenes of the other side of the moon, of the journey in space about the barren world, and of the earth from nearly a quarter of a million miles out in space will be flashed on newsreel screens before breathless audiences.

When the photographic data accumulated by the survey space ship have been integrated with that of the astronomical observatory, the landing-site for the first space ships to place men and equipment on the moon will be chosen. Factors in selecting the specific point of descent are many, including, for example, the length of anticipated stay on the moon. The area selected cannot be too mountainous if the unwieldy space ship is to land. The first space ships will land on that side of the moon which faces the earth so that constant communication may be maintained with the home planet. The landing-site cannot be too close to the lunar equator, since the temperature there is a constant 220° Fahrenheit above zero. Even the time

of departure depends upon the relative positions of the moon and the space station about the earth. Every two weeks the space station and the moon are in the precise position which will place the ship on its destination within five days, with the minimum expenditure of power required to break free of the earth's attraction.

Almost all individuals and organizations concerned with space travel agree with the foregoing facts. However, the character of the space ships employed to make the journey through space with men and equipment is at present the centre of heated controversy which once more involves the two conflicting schools of thought on space travel. Shall we adopt the "practical" approach or the "grandiose" effort?

Again it is von Braun who has touched off the conflict of opinion with his proposal for constructing three huge space ships at a cost of 500 million dollars. Each such space ship, requiring six months to construct in space, weighs 4,370 tons when fully fuelled and loaded with men and equipment. The construction project would require the transportation of an unending flow of equipment, supplies, and man-power from the earth. Each of the von Braun space ships is 160 feet long and 110 feet across at the base. Each is equipped with 30 rocket motors and pressurized personnel spheres with five decks. Two will be passenger vessels designed to carry 20 men to the moon; the third will be a cargo ship carrying ten men and 285 tons of supplies.

Each of the passenger space ships requires 18 fuel tanks with nearly 800,000 gallons of hydrazine and nitric acid. Four of the fuel tanks are spheres more than 33 feet in diameter, which carry 580,000 gallons of fuel and are jettisoned after the propellants have been exhausted in the power manœuvre required to leave the satellite's orbit. Other tanks carrying fuel for the landing on the moon are

A modification of a British proposal for a lunar space ship (by R. A. Smith) shown
49 after landing on the moon's surface. The egg-shaped vehicle would be constructed in space in the satellite orbit and carry several men to the moon for initial survey purposes.

Though heated arguments still rage among rocket engineers, in their discussions
50 of the future, as to whether or not colonies will be established on the moon, and how those colonies will be transported through space to the earth's satellite, the only elaborately detailed plan yet presented publicly on a scientific basis for this purpose is that advanced by Dr. Wernher von Braun. He proposes three tremendous space ships weighing more than 4,300 tons *each*, merely for a six-week stay on the moon in space ships similar to that pictured here.

The first lunar expedition sets out from the von Braun-design space ships. Moving
51 through a deep cavern between the lunar mountains, caterpillar-tread tractors carrying supplies and men advance slowly across the treacherous surface of jagged rocks and pumice.

Construction of the permanent lunar base gets under way. Specially-designed
52 bulldozers, power shovels, and diggers transported to the moon begin to gouge a tremendous cave from the side of a lunar mountain. Work will continue on a 24-hour basis to carve out a sufficient area within the mountain to begin fabrication of the permanent installations.

Within the fast-growing lunar base, a power drill pounds its way into the mountain-
53 side. Steel girders and beams from dismantled space ships are set up within the cave installations as fast as the work progresses.

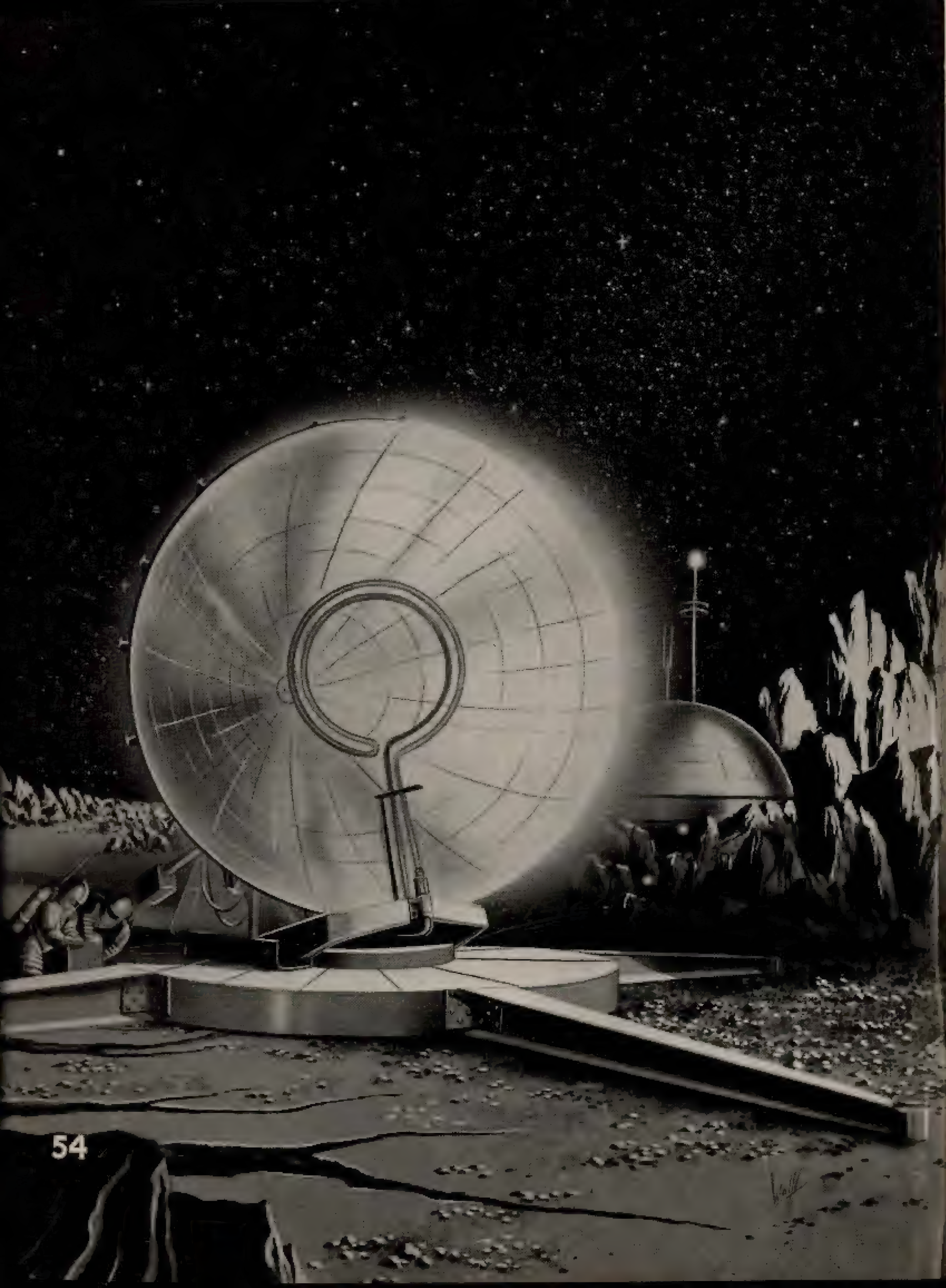
Augmenting the nuclear reactor will be solar mirrors to power much of the
54 equipment utilized by the lunar base. During the two-week lunar day period the tremendous heat of the unfiltered solar rays could be harnessed by special solar boilers to provide great power. Nuclear reactors would provide necessary power during the night period.

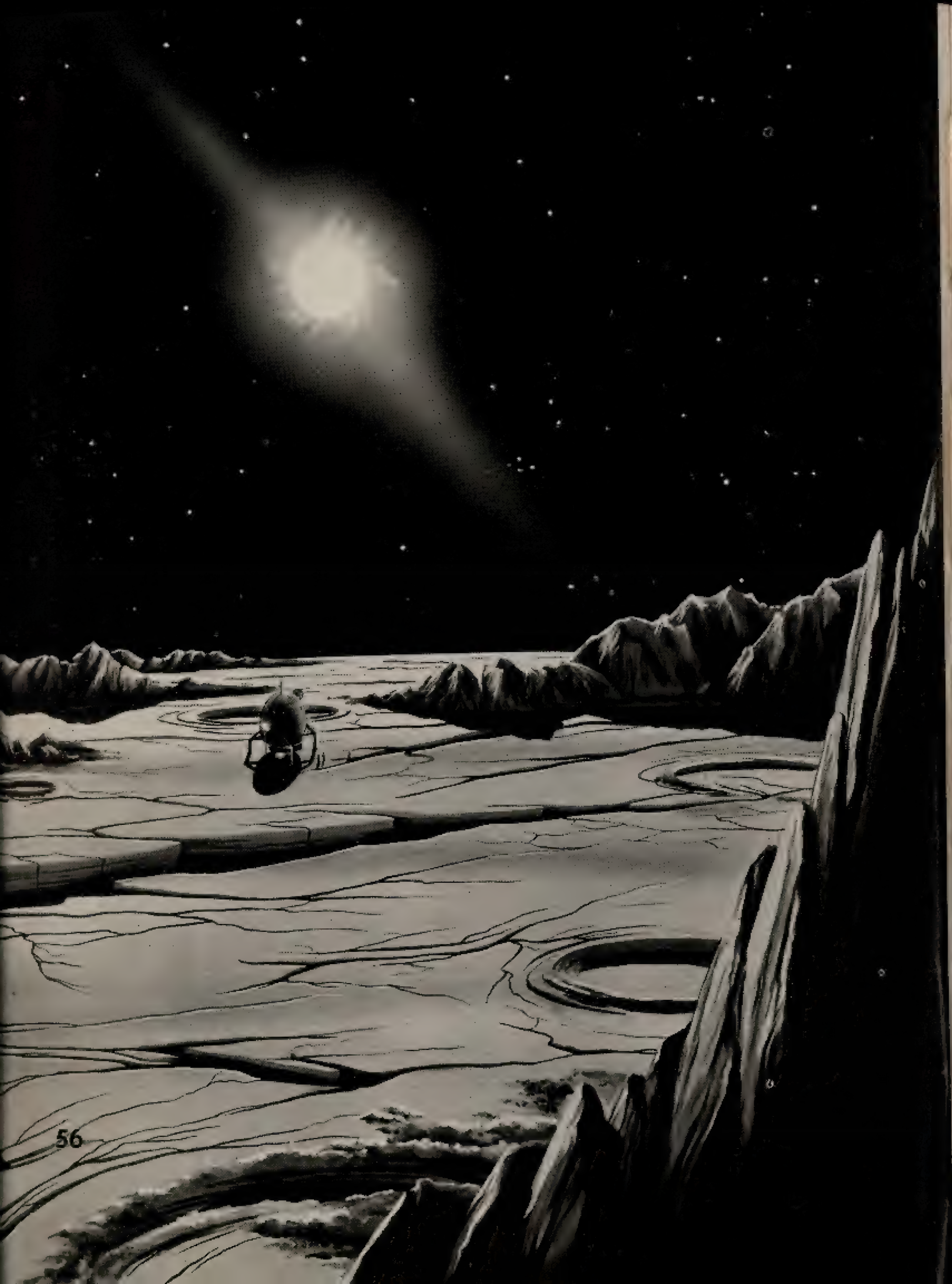
If the lunar base for rocket attack against the earth were ever built, this is what
55 a missile launching might look like. The rocket, foreground, is shown immediately after the motor was started, the firing-cable at the left breaking away.

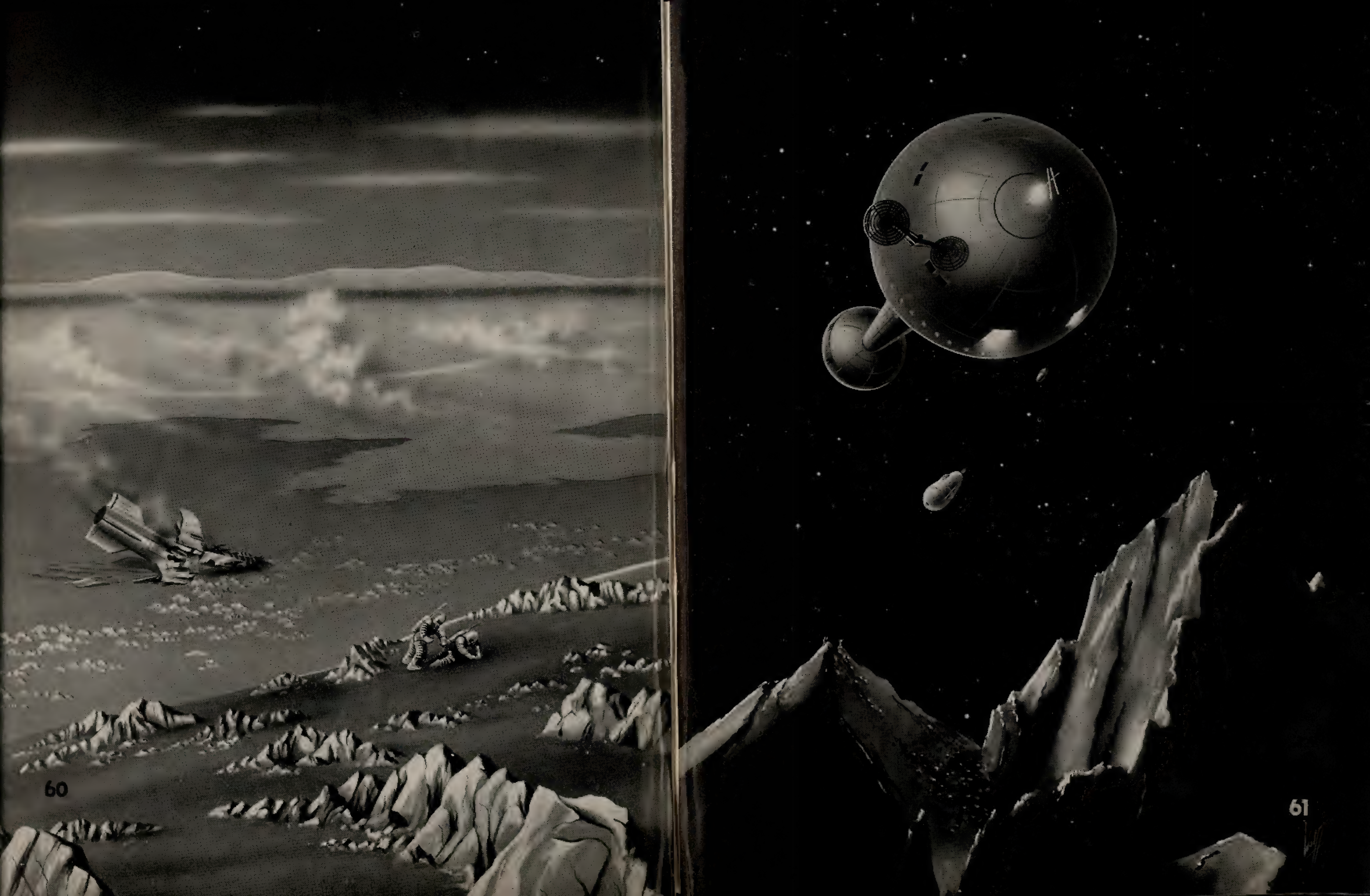
If a manned space ship ever descends to the seared, forsaken surface of Mercury
56 that for ever faces the sun, it will land on a baked, burning surface with temperature in excess of 700° Fahrenheit, which is hot enough to melt lead and tin. Closest planet to the stellar furnace which is the centre of our solar system, one half of little Mercury for ever is bathed in tremendous heat, while the other half, facing away into space, is a paradoxical extreme of bitter cold and perpetual darkness.

Contrary to the illusions of science-fiction-fed readers, Venus, the "sister planet"

Captions continued on page 149







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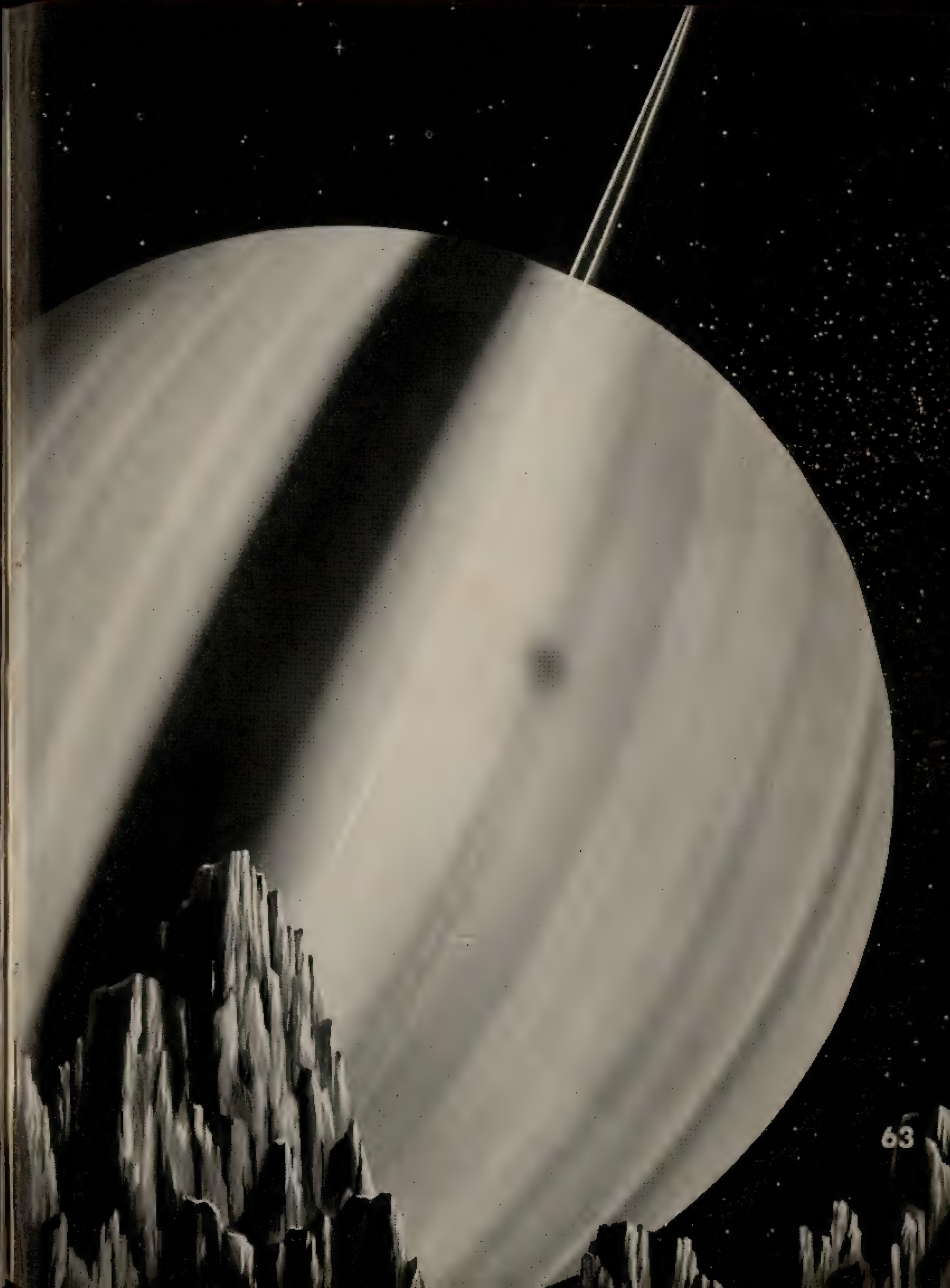

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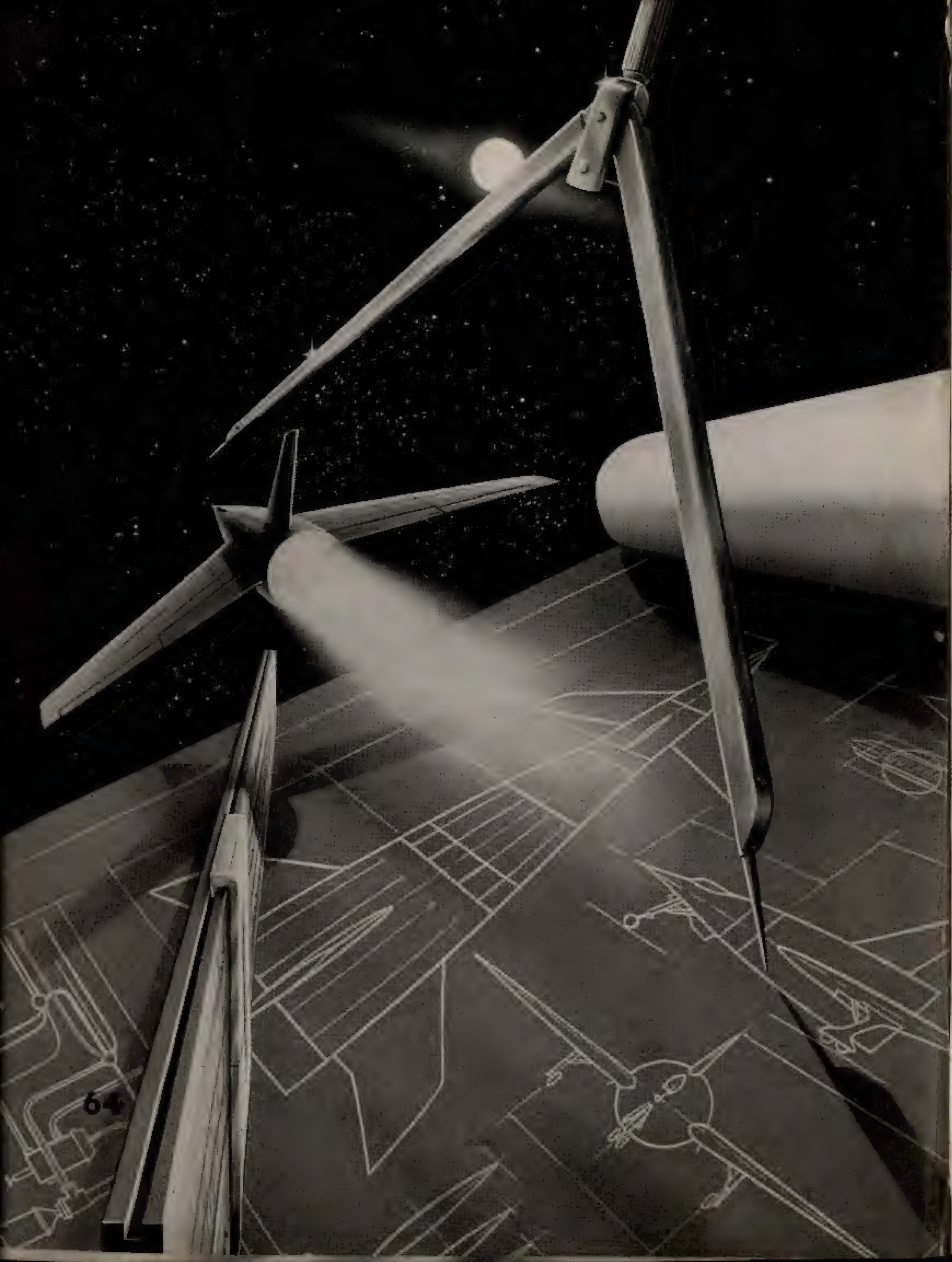

of the earth, is not a lush jungle paradise but actually a world of violently swirling 57
sandstorms, great heat, and carbon dioxide.

Journeying from the earth to Mars, this winged space ship narrowly escaped a
devastating collision with a meteor as it orbited in free fall towards the red 58
planet. In this accident, where the speeding missile penetrated and exploded through the wing section, the main compartments were spared destruction and explosive decompression. Spacesuited crewmen are repairing the damage and affixing new steel plates to the damaged area.

A nuclear-powered space ship orbiting about the planet Mars, with the glistening
polar cap visible at the lower right. In left foreground the tiny moon Deimos 59
is seen in its orbit about Mars.

In this first attempt to land on the planet Mars, the space ship seen wrecked
in the background crashed on the surface and was almost totally destroyed. Two 60
spacesuited survivors struggle away. When their air tanks are exhausted, the first earthmen on Mars will die—the thin air of Mars, with a pressure equal to that 50,000 feet above the earth's surface, is too meagre to support life.

The nuclear-powered space ship, shown here in a dumb-bell design as often pro-
posed by Arthur C. Clarke, ex-Chairman of the British Interplanetary Society, is 61
the ideal design for travel between the planets. The nuclear reactor contained in the heavily shielded smaller sphere is sufficient to propel the space ship in orbit-to-orbit journeys to and from various planets. Here, two space taxis from the space ship are seen moving to the surface of a great asteroid (or planetoid) orbiting about the sun between Mars and Jupiter.

Colossus of the solar system's nine planets, Jupiter is one world that will never
be visited directly by man. Nearly 90,000 miles in diameter, the surface conditions of 62
this incredible goliath world are almost impossible to imagine. About 40 miles deep in Jupiter's atmosphere, below the level where the pressure is equal to that of earth's atmosphere, the ammonia and methane gases of Jupiter are as dense as platinum!

Often described as the Queen of the Planets, Saturn is a world almost as large
as Jupiter, with a diameter of 79,000 miles. Despite its immense size, the surface 63
gravity of Saturn is approximately equal to that of earth. No man will ever descend into the raging atmospheric maelstroms, however, which greatly resemble the wild surface conditions of Jupiter.

Space can be conquered, but only through years of critical evaluation of the
problems of rocket engineering, chemistry, metallurgy, space medicine, elec- 64
tronics, and the related scientific endeavours so vital to the success of any space-travel programme. The engineer, scientist, doctor, steel worker, electrician, administrator, spaceman, and many other personnel talents must be joined together into a nation-wide organization for the eventual conquest of space.

left behind when the ships return to earth to eliminate their empty weight during the return journey. Von Braun estimates that three-fifths of the original budget of 500 million dollars will be expended on fuel alone. Furthermore, by starting on the space-satellite project now and working at full speed on all phases of the programme, von Braun believes that we can set these three tremendous ships down on the moon's surface by 1977.

The most startling element in the entire proposal is its immensity. When one considers the vast logistical support required to carry out this grandiose scheme for exploring the moon, one cannot fail to realize that the over-all estimate of even half a billion dollars is too conservative. Von Braun's estimate assumes that the expensive lower steps of the rocket craft which will transport supplies and more than 12,000 tons of fuel can be recovered for repeated use. He ignores the vital facts that we must anticipate the loss of at least 10 per cent of the booster stages used in the flights and that we must almost certainly expect the occasional destruction of an entire 265-foot shuttle rocket. The intricacies and all too frequent unreliability of multimotor space ships, the successful operation of which demands complete efficiency under conditions of tremendous temperature and velocity; the complicated electronics equipment, and dependence upon hundreds of miles of electrical wiring, of which only a single part need fail to cause disaster: all of this surrounds the project with an inevitable percentage of operational mishaps which will boost enormously the anticipated costs.

Furthermore, the von Braun estimate allows only 200 million dollars for construction and for the cost of all salaries, equipment, instruments, and other material involved. Such estimates are unreasonable. The shipment of fuel to the satellite orbit by the three-

stage shuttle rockets, assuming a maximum payload for each rocket for 40 tons, will by itself require at least 300 successful, accident-free launchings and deliveries. To transport 2,400,000 gallons of chemical propellants into space, the shuttle rockets themselves must burn up 1,800,000 tons of fuel! We must add to this figure the cost in fuel and money of transporting construction equipment, structural members, and accessory equipment for the three lunar space ships.

It becomes obvious that von Braun's financial and temporal estimates can serve only as a point of departure and must be greatly increased. This can be demonstrated by reference to the known cost and time requirements in the aircraft industry. We already know that with existing techniques, an experienced industry, skilled man-power, and vast research equipment, a minimum of ten years under the highest priority is required to place in operation a conventional aircraft design. Despite this, von Braun assumes that his grandiose project, which contemplates activity in fields as yet unproved, vehicles more than 20 times the all-up weight of the largest aircraft ever constructed and still of doubtful value, and the split-hair precision required by immense rockets, can be accomplished in less than three times the time demanded by conventional aircraft construction. Only through the discovery of radically new fuels or rocket techniques and their application on an extensive scale could the 25- to 30-year estimate of von Braun achieve reality.

Shepherd and Cleaver of the British Interplanetary Society, previously mentioned, raise further doubts as to the practicability of von Braun's moon-ship design. According to these two authorities, the 800,000 gallons of chemical propellants required will weigh a total of more than 4,200 tons. This leaves an allowance of approximately

100 tons to accommodate the weight of the pressurized living-compartments, the crew and supplies, the structural weight of steel girders, the fuel tanks, the rocket motors, the instruments, and other equipment! While Shepherd and Cleaver do not state definitely that von Braun's technical estimates are impossible, they obviously believe that the proposals made in *Collier's* and in von Braun's more detailed book, *Das Marsprojekt*, enjoy only a marginal possibility of success. They point out the fact that even a slight increase in final weight would seriously handicap the success of the venture.

There is little justification for such tremendous outlays of funds, equipment, and man-power to accomplish the first landing on the moon. The immense undertaking suggested by von Braun calls for the transportation of 50 men and the supplies and equipment needed to support this expedition for a six weeks' stay. This equipment would constitute not only the necessary scientific essentials but complete caterpillar tractor trains and similar devices.

The first space ship to effect a surface descent to the moon will in all probability remain there for no more than two weeks. The space ship, much like its survey vehicle predecessor, will appear to be a haphazard mass of fuel tanks, motors, girders, pressurized chamber, and other equipment bolted together within a steel-girder framework. It is likely that no more than a half-dozen men will be accommodated with equipment to conduct an initial survey of the moon, paving the way for later and more elaborately equipped and staffed expeditions. The fuel tanks exhausted in the departure from the satellite and in the landing manœuvres will be abandoned on the airless world along with much scientific equipment which can be utilized at a later date by succeeding groups.

Man on the Moon

When the first men descend from their space ship to the surface of the moon, they will be faced with two weeks of life on a dishearteningly inhospitable, strange, lifeless, and even terrifying world. To avoid the tremendous heat on the surface during the two-week "moon-day" period, the space ship will probably land in the "night" half of the satellite. Even under these conditions there will be considerable illumination across the rocky world, a garish green-tinted light reflected from the distant earth.

Because no atmospheric dust, air, or water vapour exists to refract and distort light waves, the magnificent panorama of space with uncounted stars gleaming in a jet-black sky will always be visible to the spacemen. The full earth will appear as a brilliant, swollen ball in the skies, of a size several times larger than the moon appears to us. Even during the day, when the sun casts its painful brilliance across the surface, the horizon will terminate in the absolute blackness of space instead of in the familiar diffusion of light so well known on the earth. A searing ball of flame in the sky, the sun constantly throws out flaming streamers of fire for many thousands of miles from its surface.

A layer of dust, composed of pumice, covers most of the moon surface. Present investigation supports the claim that this pumice layer is on the average a quarter of an inch deep; some scientists, however, insist that the covering may be several inches in thickness. Colour will be conspicuously absent. Instead of the deep, rich shades familiar on earth, there will be a predominance of dull browns and greys, intermittently mixed with faded reds. The only relief will be the greenish earth, the black of space, and the glaring brilliance

of the sun. Men walking across the surface will kick up clouds of fine pumice, which will settle almost as quickly as it rises.

There will be no sound on this airless, barren world, no covering of soil and plant life, no streams or lakes. The endless panorama will be one of crater walls, jagged mountain peaks, rills, and repeated crevasses. Thousands of meteorites, the majority microscopic in size, shower down incessantly upon the surface. The larger ones throw up spurts of pumice in a fine spray; an occasional shower sends a concentration of particles crashing silently across the plain.

The scientific expedition will utilize the space ship as its base of operations. Since its meteor bumper is as effective as that surrounding the satellite in space, the men are protected against all fast-moving particles of normal and expected size. The chances for collision with a meteor which could wreck the space ship are as remote on the moon as in the satellite orbit.

The tenacious popular belief that the moon is a dead, changeless world is giving way to a new concept of conditions. Where once the best scientific opinion held that the moon was absolutely unchanging in its surface features, today this belief is seriously questioned. For all practical purposes, it is true, the moon is barren and dead. But in the strictest sense of the word, as latest scientific investigation appears to reveal, there is change on the moon surface, and even the possibility of atmosphere and plant life. Telescopic studies conducted in recent years reveal unexplained radial bands appearing in a dozen or more craters which hint at a very low order of vegetation. It is intriguing to imagine the possibility that some form of tenacious plant life has managed to exist on the surface of a world so hostile to existence.

Several factors govern the ability of such a planetary body to retain an atmosphere of mixed gases. On the earth these factors favour

not only the retention, but also the natural production, of certain gases such as oxygen by the existing great areas of vegetation. The factors favouring atmospheric retention on the earth, however, do not apply to the moon. It is characteristic of gas molecules to exist in a constant state of agitation, with the lighter elements achieving velocities as great as six miles per second. The gravitational mass of the earth, establishing an escape velocity of seven miles per second, retains these gases as a permanent atmosphere. However, the moon, with an escape velocity of only 1·5 miles per second, must have lost most of its gaseous constituents many millions of years ago. The lighter gases, with a faster rate of speed, "leaked off" into space first and were followed by the heavier, slower gases.

Theoretically the moon should be totally airless. If there were any atmosphere on the moon, we might determine its existence not through direct observation but by watching the passage of the moon in its orbit directly before a star. If an atmosphere existed, the star would momentarily flicker before disappearing beyond the lunar curve. Instead, it snaps out of sight instantly, indicating that the moon is airless. The "test," unfortunately, is not a final one.

A lunar atmosphere might be detected by telescopic observers as a twilight witnessed near the cusps of the crescent moon; in late years some astronomers have actually laid claim to sighting such a twilight. The difficulty in accepting this tenuous evidence is that the supposed lunar twilight and the light reflected from the earth may be one and the same. Since earthshine on the moon is 60 times greater than is moonshine on the earth, it unfortunately masks any possible lunar twilight.

The most recently observed phenomena—meteor passage through a lunar "atmosphere" and surface mists—offer greater clarification of the mystery. Dr. La Paz of the University of New Mexico,

in 1938, theorized that the tremendous number of meteor strikes against the moon's surface should create a minimum of 100 visible annual impacts on the dark parts of the earth-turned hemisphere of an atmosphereless moon bright enough to be visible from the earth. No such visible spots have been reported. There have been cases of reported brilliant flashes above the moon surface, which give rise to serious consideration of a lunar atmosphere. Only 20 of these reported incidents appear to be meteor flare-ups, not meteors flaring in the earth's upper atmosphere and projected against the lunar background. Their particular characteristics differ sufficiently from the familiar meteor tracks to constitute a definite distinction. If such evidence of meteor trails above the moon's surface can be supported, then it would appear that an extremely tenuous atmosphere does exist on the moon. The term "atmosphere" is employed loosely in this sense, since the density of such gases could be no more than one ten-thousandth that of the terrestrial atmosphere. For all practical purposes the moon would remain essentially airless.

In support of the claims for a lunar atmosphere, astronomers have reported reliable observation of lunar mists filling certain craters. On occasion, when seeing conditions were perfect and adjacent details were sharply defined, astronomers have sighted mists completely filling the boundaries and floors of walled plains and craters. These observations date back to 1865 and include definite surface changes such as would be created by shifting vapour. The final conclusions strongly indicate the existence of some form of atmosphere on the moon.

Unless the spacesuited explorers exercise constant vigilance, death can come easily and suddenly on the moon. A spacesuit torn by a jagged piece of rock will cause an agonizing explosive decompression. Unwary passage over thin-crusted, deep crevasses can

mean death. A man who weighs 180 pounds on the earth burdened with an equal 180 pounds of spacesuit, lead boots, oxygen tanks, radio, and other equipment, for a total 360 pounds, will weigh only 60 pounds on the moon. One might suppose, then, that a fall on the moon would not be dangerous, since its gravity is only one-sixth that of earth. On our own planet, however, a man falling from a bed can sustain as much harm as he might suffer by falling off a ladder. The body still has inertia on the moon, and despite the lighter gravity a drop to the surface can be dangerous.

There will be no lack of spectacular sights on this unusual world, for lofty mountains towering even higher than the greatest peaks of earth stretch across the lunar surface. Two hundred miles in length and with peaks rising to a height of more than 20,000 feet, the Apennine mountain range forming the south-western boundary of the Mare Imbrium is perhaps the most impressive on the moon. In the southern hemisphere the stupendous peaks of the Leibnitz Mountains tower more than 30,000 feet above the satellite's surface, reaching even higher than Asia's mighty Everest. The summit of Dorfel Mountain rises more than six miles from the flat lunar plain. Sharp, jagged, unscarred, and free from the eroding forces of wind and ice, these lunar peaks are comparatively more than four times as high as the tallest mountains on earth. To approximate (proportionately, that is) the incredible lunar mountain formation, Mount Everest would have to soar 116,564 feet above the earth.

An observer watching the awesome spectacle of towering mountain ranges and lofty peaks would find the scenic view even more unusual. Because of the moon's smaller size, the visible surface would extend for only approximately two miles to the horizon before it curved away and out of sight. On the earth the distance to the horizon extends to as much as 20 miles.

Although lack of colour characterizes the moon's surface, and it looks predominantly grey and black, with dull browns and reds appearing in the rock formations, there are several areas which promise variety. Inside the great crater of Grimaldi and in the Mare Crisium, astronomers have noted greenish hues. The brilliant east wall of the crater Aristarchus has been observed to possess a distinct bluish glare. At least one crater with a distinct red colour has been sighted; all these colour indications, unfortunately, may have been the questionable result of eyes strained from prolonged visual study.

For centuries astronomers have photographed, charted, and classified the lunar surface, evolving a detailed map which lists by name and number more than 30,000 lunar craters. The largest and most elaborate of all such maps is 25 feet long. Perhaps the most intriguing and important of all lunar surface formations are the craters; these exist in various sizes, from the tremendous Bailly crater, fully 170 miles in diameter, to innumerable pits less than 100 feet across from rim wall to wall. Some of the larger crater rims extend more than 10,000 feet above the surface; in others, fairly large mountain peaks stand in the crater centres. Near the moon's centre is one of the larger, circular-walled formations, the crater Ptolamaeus, with a diameter of 90 miles. Its rim walls average 3,000 feet in height; one rim peak juts 8,000 feet above the crater's surface. Within the great crater centre a craterlet, four miles across, rises from the surface. Deeper than Ptolamaeus, the Arzachel crater has rim walls extending more than two miles above the depressed interior. In the centre of this 56-mile formation is a large central mountain; this central peak is common to numerous craters, both large and small.

Extending from many craters are the most enigmatic of all lunar features: the bright rays which stretch more than 1,000 miles

from their source. The most famous of these ray centres are the craters Copernicus and Tycho. Where and how these rays originated is a source of considerable astronomical speculation and the basis for many conflicting theories. No acceptable solution has yet been found, although the majority opinion contends that the bright ray formations resulted when basalt was powdered white by massive and extreme-velocity meteor impact, spraying the blasted remnants of this colossal crash radially across the surface.

Although we describe the circular-walled formations on the moon as craters, many of these deep and immense features are actually shaped in the form of a shallow dish. An observer at the centre of many of these areas could not see the distant crater walls rising above the surface and would believe he was standing on a flat plain.

Many other surface characteristics will occupy the attention of the scientific expedition on the moon. There is the great so-called Straight Wall, extending more than 60 miles across the surface. Distinct and clear on photographs, the wall is believed to have been created by a major surface upheaval; moving from west to east, the ground plummets abruptly for 300 feet. The Straight Wall could appear as a sheer precipice; to an observer along its base, on the other hand, it would appear as a towering cliff extending beyond the horizon.

The expeditions may determine the origin of the moon and solve many of the questions puzzling astronomers about craters, surface rills, rays, and other formations. One theory of the moon's origin, among many, suggests that it was torn from the earth somewhere in the area of the Pacific Ocean; this belief, however, receives little support. Another theory claims the moon was composed billions of years ago from a great mass of rock, metal, and ice orbiting about the earth like the rings of Saturn and that some gravitational

disturbance formed this into the spherical shape we know today. By firing rockets with explosive war heads into the moon surface and recording the impact and shock waves by seismographs many miles away, we shall be able to determine its interior composition. If the seismograph records a clear and loud shock wave, this will indicate that the moon is a solid layer of rocks and metallic ores. Muffled shock waves will indicate a mass of rock which has not solidified; very faint waves, or none at all, may indicate a molten interior, such as that possessed by the earth.

Lunar surface and subsurface materials will be surveyed and samples will be returned to the earth for exhaustive studies. The existence of a lunar atmosphere and of basic forms of vegetation within crater walls will be determined. Instruments will search for a magnetic field and magnetometers will ferret out a possible iron core of the little world. Geiger field-survey counters will search for radioactive ores, for the moon may prove to be a rich source of raw elements in short supply on the earth. Tests in bright sunlight, in shadow, below the surface, and under various conditions will be made to record the extremes and fluctuations of temperature. Scientists will attempt to make an accurate count of the numbers of meteoric impacts with the surface. Cloud chambers and other research instruments will measure cosmic-ray intensity to determine whether or not the powerful radiation is different in strength and composition this far out in space.

All these experiments, and dozens more, will be made on a round-the-clock basis by the scientific expedition. With the space ship in the night portion of the moon, power will necessarily be supplied by equipment carried in the ship. Other space ships, travelling to the moon on future occasions, may establish expedition headquarters in the sunlit part of the moon and derive power from solar

mirrors on the airless surface. Any permanent installation will probably utilize both solar power and a source of atomic energy, well shielded by thick mountain walls.

Communication across Space

In considering radio communication through space from the earth to the moon, from the satellite to the moon, or from satellite to a space ship, we must realize that comparisons of conditions on the earth and in space are meaningless, since planetary conditions do not exist in space. Beyond the earth's atmosphere in the vacuum of space, radio waves travel in straight lines through an absolutely transparent medium. There are no natural barriers; there is nothing to cause reflection or refraction which can cause signals to vary in power. While interference exists in space, it is of a character which can easily be overcome. Galaxy noise and waves radiated from dark stars are examples. Fortunately these are weak, with a spotty and varying spectrum which space radio communications can readily avoid.

Thermal noise caused by solar activity which radiates along a continuous spectrum throughout the galaxy is interference which does not have definite radiation frequencies. A third type of cosmic interference is caused by erratic solar radiation which rises and falls with sunspot activity.

Considerable research into the field of radio communication across space undertaken by George O. Smith, radio research engineer of the Emerson Radio and Phonograph Corporation, was publicized in 1952 at the Second Annual Space Travel Symposium in New York City. This provides us with the clearest insight to date on this subject.

Mr. Smith points out important factors in voice-radio communi-

cation between the earth and the moon which are usually overlooked in discussions of in-space communication. The efficiency of such communication depends upon many considerations, among which the individual ear, individual voice, and the importance of the message play a major part. The speaker's voice affects the acceptable signal-to-noise level for the listener. Some voices cut through noise levels when others are completely blanketed; the results are the product of a particular enunciation, of voice pitch, and of the rapidity with which the words are articulated. Hearing ability is a vital factor, since some people are extremely sensitive to bursts of noise which cut into their concentration level and cause them to miss parts of a message. Other people can listen to a conversation conducted with surrounding high noise levels and not miss a syllable.

The atmosphere between the earth and the moon is reasonably transparent to microwave bands, which employ frequencies lying approximately between 1,000 and 30,000 megacycles. These microwaves are extensively used in the several radar systems; as a consequence we have gained considerable experience over many years in utilizing them efficiently. This intimate knowledge enables us to predict their performance with considerable accuracy. Microwaves are also excellent carriers for space radio because they can be confined in a tight beam by using antenna arrays of a convenient size. The signal reflectors can be adapted for earth stations, space satellites, and space ships with equal ease. A six-foot disc of aluminium is probably the most satisfactory equipment for basic communication.

Earth-moon communication will differ considerably in time lag from ordinary point-to-point communication. Radar or radio waves complete a round trip between earth and moon in 2·6 seconds. This means that there must be a comparable lapse between each ques-

tion and answer. The greater the distance a space ship is from the earth, the greater will be this time lag in message transmission. In communicating with a station on the planet Mars, for example, there will be a time lag of about six minutes between statement and rejoinder.

Since little interplanetary conversation will be on a personal level, but will be concerned mainly with the transfer of technical data, instructions, and similar messages, the best means of transmission through space will probably be a radio-teletype system. Messages carrying specific facts and figures are thus made available as quickly as is the spoken word, and no mistake can be made through misunderstanding of questionable items. Operators writing down messages would not be required, their anticipated errors could be eliminated, and the message is automatically recorded for future reference. With the teletype machine, it is possible to punch-tape the received signal at the same time that the typing section is recording the message. At the end of such reception it is possible to retransmit the tape recording to the point of origin. Any discrepancy between the original transmission and the reply-copy can be investigated and corrected.

One of Mr. Smith's suggestions merits serious consideration. Designers of satellites and space ships have included as a source of power some form of solar oven such as the mercury boiler system. Smith suggests what he considers a far more satisfactory arrangement; this contemplates eliminating the mirror and running the mercury through a heat exchanger located in the radio equipment. A three-centimetre magnetron in a radar unit delivers both tremendous power and sufficient heat to warm a four-room house. The major problem may eventually involve elimination of the heat rather than its application as a power source.

8

On the Moon to stay

Permanent research and industrial installations may follow the landing of the first expeditionary ships on the moon. There is reason to believe that the moon may become the key to man's ultimate conquest of the entire solar system. It is anticipated that permanent lunar installations will undertake scientific and technological studies to accelerate that conquest.

Before we delve further into this subject of permanent installations a quarter of a million miles across space on an airless, barren world, we require some explanation to clarify the relationship between the lunar base and the space ships and space satellites. The development of the space ship, evolving from years of guided-missile experimentation, is a goal within the capabilities of the existing rocket and allied industries. Although the intricate engineering problems involved are numerous, they are already completely identified. While presenting a host of obstacles, the solutions to which cannot be tested until man is actually in space, artificial satellites are within the foreseeable capacity of a constantly expanding rocket industry.

The ultimate goal of permanent lunar bases, on the other hand, is dependent entirely upon the successful space ship, the established space satellite, and the ability of man to adapt himself to the hazards

and rigours of space. Not only must the space ship and satellite be proved mechanically reliable; they must in addition effect a military and scientific gain commensurate with the considerable expense in time, man-power, finance, and *matériel* involved. Only if such activity receives the unbridled and enthusiastic support of industry, science, and the military agencies will the lunar base be seriously contemplated.

The preceding chapters have provided some indication of the extensive logistical support necessary to establish the space satellite and carry out the initial exploration of the moon. Any endeavour which envisages permanent lunar bases can promise success only if it recognizes that they must become almost completely self-sustaining in their requirements for air, water, heat, and power. The lunar base must promise eventual recompense to its creators not only in scientific accomplishment but in hard economic terms. Eventually man will have at his disposal the technological means to travel through space without the restraint imposed by chemical rockets of limited performance. When that time comes the industrial exploitation of the moon is likely to become a reality.

Any discussion of a permanent lunar installation must inevitably promise less accuracy than predictions of space-ship construction and operation. The development of space ships is a science; the description of a lunar base involves considerable speculation. Science and imagination, however, can provide a realistic yardstick of the future. The following description of the lunar base, therefore, rests entirely upon existing fact and logical deductions made therefrom. The reader must realize, in reading this description, that it is impossible to predict with accuracy scientific innovations at present beyond our ken. An outstanding example of scientific and technological unpredictability is the fact that, while ancient seers predicted in

broad terms many of the present products of science, they never envisioned in any form today's automobile. The internal combustion engine, today a common implement, was beyond the imagination of the ancients.

The concepts of artificial installations on the moon here given rest upon a realistic assumption of scientific developments in space travel. This restraint upon imagination imposes limitations on the writer inclined to simplify the problems involved. If we assume, for example, that science will in the near future perfect some device which will effectively neutralize gravity, then the conquest of space becomes a matter of routine. Perhaps such devices will one day become a reality, but at present such hopes must be based on little more than pure speculation.

Lest the reader reject lunar installations as beyond hopes of attainment, let us remember that many of the facilities which this day and age accept as a matter of course were "impossible" much less than a century ago. Electronics, atomic bombs, nuclear power, radio, television, diesel engines, the wonder drugs, fluorescent lighting, plastics and synthetics, electronic computers, highway systems, great steel bridges, skyscrapers, aeroplanes, movies, and a host of others would have seemed incredible 100 years ago, and for the most part were even beyond the powers of the imagination.

What we consider impossible today will eventually become prosaic. Our descendants will probably consider this "modern age" hopelessly enmeshed in archaic ignorance.

The Lunar Base

Since the space-ship cabins used to transport the working crews to the moon are necessarily cramped for living and working space, the first task of the lunar construction force will be to set up temporary

living quarters. Therefore, several of the great moon-ships are dismantled soon after landing and pressurized sheds erected from prefabricated parts. To facilitate the rapid completion of these living-quarters, the space ships are originally assembled in such a fashion that, upon dismantling, the parts can be pieced together rapidly.

Curved steel sheets are bolted and welded together to form sheds which resemble Quonset huts. Once the framework is completed, plastic-nylon rubberized bags are inflated inside. The surrounding steel enclosure is covered with an additional steel shell to form a meteor bumper. Additional protection against meteor penetration is provided by erecting the pressurized steel sheds along the base of a mountain or beneath an overhanging cliff.

These facilities for protection against meteors also assist in controlling temperature within the sheds. During the two-week day period when the temperature of the moon's surface soars to more than 200° Fahrenheit, the outer steel shield acts as a barrier to heat transmission; maintenance personnel will worry more about refrigerating the interior than about heating. Night periods on the moon will require heating from a permanent power installation, since the sunless period of two weeks renders solar mirrors periodically useless.

When the sheds are fully sealed, with the inner walls kept rigid by the internal air pressure, equipment is installed for personnel. Bunks for sleeping, sanitation facilities, lighting, temperature controls, communications equipment, food supplies and cooking equipment, administrative files, medical facilities, and air and water recovery equipment, are established in place. A double set of airlocks to assure safety for personnel without spacesuits is built, and the several sheds are connected by small tunnels, each with its own separate airlock arrangements.

Each personnel shed has a separate maintenance and servicing

room for the spacesuits used by workmen. Suits are carefully inspected after every working period spent in the vacuum on the moon's surface, since close contact with sharp rocks may gash suit layers and lead to explosive blow-out.

Primary power facilities are provided by ordinary diesel or gasoline engines, operated within a sealed room inside the pressurized shed. It will be impossible to avoid a temporarily great consumption of air for this purpose. As soon as possible, a nuclear reactor will be set up as a permanent power source for all shed facilities, with power cables leading to each living unit from the central nuclear power station. Should the nuclear reactor misfunction, the emergency generators will be employed to maintain heating and refrigeration, provide lighting, continue ventilation, and provide necessary power to the living quarters until the reactor can be repaired.

Communication equipment will be transferred from the dismantled space ships to the living-quarters to maintain contact both with the space satellite orbiting about the earth and with the earth stations direct. Direct wire communication will be established between sheds and extended to any construction site where constant communication is indispensable.

Proceeding simultaneously with construction of the living-quarters, workmen will erect a radio mast extending 50 to 100 feet above the moon's surface. All communication between spacesuited workmen must, of course, be carried on by personal radios. Owing to the moon's "close" horizon, rugged features, and lack of an ionosphere, effective radio transmission range will probably be no greater than two miles with the radio six feet from ground level. A high radio mast will provide communication over greater distances.

Even as the living-quarters are set up in final form, and as the machine and workshops are completed, great cargo space ships will be transporting specially designed construction equipment to the moon. Bulldozers, cranes, and power-drills operating in vacuum will be powered by enclosed turbines utilizing hydrogen peroxide and fuel-oil combinations for power; perhaps a more efficient power system may be developed by the time the moon landings are made.

It is interesting to note that the giant 4,370-ton moon-ships proposed by von Braun for the initial landing on the moon are of a size ideally suited for the purpose of "colonization." By the time man is able to begin the extensive activity required for the moon installations project, however, significant advances in the field of spaceship propulsion may reduce appreciably the 800,000 gallons of chemical propellants envisioned by von Braun as necessary for each vessel.

After living- and working-installations have been established for the crew and supplies have been stockpiled to meet all anticipated and emergency needs, construction of the permanent installations *within* the moon is started. While the personnel- and working-quarters were created from the dismantled space ships and while supplies were transported to the moon, engineers were busy selecting specific sites for permanent personnel quarters, scientific laboratories, and other facilities. These installations will be completed within great caves blasted and hollowed from the sides of mountains.

The lunar installations are regarded as long-term projects designed to last many decades. They must therefore be of the strongest possible construction if they are to withstand over a period of many years the effects of blistering heat, lethal cold, and meteor penetration, and if they are to protect the installations personnel from

extended exposure to cosmic radiation. Constructing these facilities within the lunar mountains automatically provides full protection against meteor hazards. Hundreds or thousands of feet of solid rock will be an effective shield against all but the highest energy cosmic radiation. Sealed against the vacuum of space, the living- and working-quarters enjoy effective temperature control. The danger of explosive decompression is all but eliminated through a maximum-precaution arrangement of triplicate airlocks. Danger from the penetrating radiation of the nuclear reactors is reduced to a minimum by the effective shielding of thousands of tons of rock. The cubic area of the permanent quarters can be increased at any time; enlargement of this space after the minimum requirements of living facilities are met is a much simpler undertaking than the initial project.

Temperature extremes, one-sixth gravity, an unchanging and drab horizon, utter silence, meteor-penetration hazard, spacesuit explosive decompression, and similar dangers constitute the bizarre conditions under which the construction workers must labour. Movement within the bulky spacesuits will at best be awkward; a man newly arrived on this hostile world must learn to walk anew. It will require time and practice to become accustomed to walking under conditions of one-sixth gravity. It is anticipated that workmen will wear special footgear embodying heavy lead or steel weights. Under low-gravity conditions a man could easily jump several times his own height. While his upward leap would be a simple matter, he would return to the rocky ground with dangerous impact. Until the individual has achieved practice in the art of movement under lunar conditions, the weighted shoes will be indispensable.

Lifting heavy objects will be a simple matter on the little world, and workmen will perform what will seem amazing feats of strength.

A steel beam weighing 600 pounds on the earth, for example, weighs only 100 pounds on the moon. Physical labour will be reduced, but only proportionately. While it will require only one-sixth the usual effort to lift a sledge hammer, it will still require normal muscular effort to swing that hammer, for its movement is still governed by the laws of inertia.

Specially designed bulldozers, cranes, and power-drills will be employed to carve the cave within a mountain base. As work progresses and the crews penetrate deeper into the mountain, auxiliary lighting equipment will be brought into the growing area. Even as the power-drills and bulldozers gouge within the mountain and the pulverized rock is carried outside the cave, work crews will be fitting curved steel girders from the dismantled space ships into place as overhead supports. At the entrance to the cave steel beams and the foundations for the triple system of airlocks are placed in position. Power cables are secured the full length of the cave.

Finally, the construction crews will have cut their way far enough into the mountain. With the last major structural girders in place, the airlocks are sealed and the atmospheric components released into the cave. Ventilation systems are put into operation immediately, sanitation facilities are completed, and essential requirements for eating and sleeping are installed. Food, air, and water supplies are transferred from the temporary sheds to the permanent installation. The workmen can now continue their tasks without the cumbersome spacesuits, and work schedules continue on a 24-hour basis to complete the essential quarters. Compartmentation of the great central cave permits a division of the area into sleeping, eating, administrative, and recreational quarters. Maintenance, machine, and power shops are separated from personnel facilities. Power units are transferred from the temporary generators to a connection

with the nuclear reactor. Water-recovery systems are placed in operation. Bunks, desks, and similar items are secured in place.

Before long the research laboratories are established. Separate pressurized caves are gouged from the mountain base for the construction equipment, which must be kept in operating condition for further construction. Emergency lighting and power machinery is established to replace the nuclear reactor in an emergency.

As soon as the main quarters are sealed off by airlocks and pressurized, engineers and scientists begin to install the equipment which will enable the moon base to supply much of its own needs. The least expensive means of providing an oxygen supply, of course, is through the maintenance of hydroponic gardens with efficient oxygen-producing plants. A ventilation system keeps the air throughout the entire installation constantly circulating to take advantage of the flow of fresh oxygen from the gardens.

Geologists hold that oxygen comprises more than half, by weight, of the earth's crust and that there is more oxygen to be found in earth materials than in the entire atmosphere of the planet. There is every reason to believe that the minerals on the moon also contain a high percentage of oxygen. If the botanical facilities of the moon base are insufficient to supply oxygen needs, industrial processes may extract the life-giving gas directly from the ground. The considerable power needed for this operation is supplied by solar ovens on the surface and by the nuclear reactor.

Space-medicine research indicates that the required aerosol complex of man cannot be met by oxygen alone. Whether helium can be extracted directly from the moon or must be transported from the earth is a question which can be answered only after the scientific expeditions have studied the moon at first hand.

The combination of a water-recovery system and industrial

processes extracting water from the minerals found in the moon may be sufficient to supply the station's water needs. Certainly the logistical problem of transporting tons of water from the earth to the moon over a period of many decades would tend to negate the value of the lunar base; therefore, scientists will bend every effort to establish a local source of supply.

The third major requirement after air and water is, of course, food. The alimentary requirements of the lunar base pose an even greater problem of supply than does the need for water. However, hydroponic gardens within the lunar base may furnish the greater part of food requirements. Certain foodstuffs which cannot be grown will be supplied by cargo rockets. Hydroponic gardens within the sealed moon base would also constitute an oxygen supply in addition to food necessities. The low gravity of the moon may be expected materially to enhance the productive properties of selected plants. One proposal for the creation of food envisages chemical synthesis. It is certain that whatever problems exist in these fields can be solved by the time man is ready to establish a moon base.

Although hydroponic gardens, water-recovery systems, solar and nuclear power, and the extraction of vital minerals from the moon will to a great extent reduce the supply problem, it is apparent that considerable quantities of bulk supplies will necessarily be transported from the earth to maintain the lunar base. Conducting this supply operation with fuels at present available may create a logistical problem greater than can be supported by industrial and economic returns from lunar activity. However, the solution may be provided by industrial processes on the moon which can greatly reduce the fuel problem of earth-to-moon cargo rockets. This solution depends upon the success of (1) the production of chemical propellants on the moon and (2) the development of atomic reactors for

space-ship propulsion, combined with the extraction of water from indigenous lunar minerals. Success in either of these two fields means that the moon would become the key to conquest of the entire solar system. Electrolyzed water provides hydrogen and oxygen which can be employed as satisfactory, although not ideal, fuels for an atomic-driven space ship. Which means that an industrial installation extracting and electrolyzing water on the moon could supply unlimited fuel to atomic-powered space ships shuttling between the earth and moon.

It was previously stated, in reference to depositing radioactive wastes on the ground in the area of atomic space-ship take-off, that the anticipated danger of such residual contamination has been somewhat exaggerated. It is also true that even the atomic expert cannot predict with complete accuracy the adverse radiological consequences of the forecasted space-ship reactor. The discharge of radioactive waste may prove to be of such a high concentration that we shall be compelled to confine the use of atomic space ships to in-space manœuvring. If the more pessimistic prediction proves true, then the lunar-base production of chemical fuels will be necessary to minimize the considerable burden of supplying the required propellants for earth-to-moon journeys.

Assuming that the production of such chemical propellants on the moon is possible, fuels for the shuttle-rocket journey from the satellite's orbit to the moon will be transported *from* the moon to the satellite. At first glance the transportation of thousands of gallons of chemical fuel nearly 238,000 miles across space from the moon to a point 1,000 miles above the earth, merely to burn that fuel in powering an earth-launched rocket back to the moon, may seem ridiculous. It would be were it not for one very important factor: the extremely low escape velocity of the moon.

It actually requires much more fuel to place a rocket in an orbit 1,000 miles above the earth, when that rocket ascends from the earth, than to launch a rocket from the moon into that same orbit. The seeming paradox is resolved when we realize that the escape velocity of the moon is only 1·5 miles per second, and that a space ship leaving that body need not travel much faster than 5,000 miles per hour. The earth-launched space ship, however, must fight its way through the atmosphere against the sixfold gravity of earth, and must attain a speed exceeding 18,000 miles per hour to reach its orbit 1,000 miles high.

Once the space ship from earth reaches its orbiting position, it must then wait for space tankers to ascend with additional supplies to fuel the journey from the orbit to the moon, and to permit landing on the moon, taking off therefrom, and maintaining an emergency fuel reserve.

By producing this fuel locally, space tankers would leave the moon and fall into an orbit about the earth. Meanwhile, the cargo rocket would have blasted off the earth into the same orbit, where it is refuelled by the tanker. Perhaps the one tanker could refuel several cargo rockets in a single operation. Fuel requirements for the cargo rockets would be less than normal, since only sufficient fuel to leave the orbit and land on the moon is required. Fuel for moon take-off would be provided directly by the lunar station.

Carrying this step further to include two refuellings in space would allow the departure from the orbit of the moon's planetary-bound space ships with full fuel tanks. The space ship would ascend from the earth to the 1,000-mile orbit and be refuelled by the moon-launched tanker. It would then cross space to fall into a circular orbit about the moon, where another tanker would replace the fuel expended for the earth-to-moon voyage. The planetary-bound space

ship would then leave the low gravitational field of the moon with a maximum fuel reserve for power manœuvres at its destination.

Development of the atomic space ship for interplanetary voyages, excluding actual landings on the worlds of the solar system, would obviate the necessity of refuelling space ships for interplanetary journeys. Smaller expeditionary space ships accommodated by the nuclear-powered vehicle would be required for surface exploration of the planet visited; the landing vessel would necessarily be chemically powered. If fears of residual contamination resulting from atomic take-off are eventually confirmed, then the chemically powered rocket would still be the key to transportation off the earth, for earth-moon trips, and for landing expeditionary forces on the various planets. Man's success or failure in moving throughout the solar system without bleeding his economy on earth may, therefore, rest substantially on the ultimate success of lunar industrial processes.

9

Fortress in the Sky?

A much-publicized justification for establishing permanent installations on the moon has been their use as military bases and launching-sites for guided missiles directed against the earth. The creation of the atomic bomb with its capacity for mass destruction added realism to this proposal. In the opinion of many, the combination of the moon-launched rocket with an atomic bomb war-head merited a thorough investigation of the value of the lunar rocket base.

Advocates of the moon base emphasized that the problem of launching missiles from the moon to the earth was a relatively minor one. The moon's low escape velocity would permit even a V-2 rocket, assisted in take-off by a solid-fuel booster rocket, successfully to make the trip across space. Aware of the difficulties of missile control against specific terrestrial targets, the moon-base planners assumed that they could overcome this problem by electronically computed launchings, which would compensate for the moon's movement about the earth and the earth's rotation as it affected direction to targets. When the missile neared the earth, ground stations would take over control as the rocket plunged through the atmosphere, and direct it unerringly to its target with any one of a number of adequate directional systems. They also contemplated

missile-control co-ordination by space satellites from which observers could direct the missile visually through the atmosphere.

Furthermore, the advocates of the moon base proclaimed that, unlike the satellite, the moon could not be destroyed by hostile rockets. Installations could be well hidden and protected within lunar mountains, since the extensive surface area permitted adherence to the military expedient of dispersing installations. If the satellite control station were destroyed by enemy action, the moon-launched rockets could depend on earth guidance. Industrial facilities operated by the permanent forces stationed on the moon would enable the military installations to become largely self-sustaining, and over a period of many years would prove less costly than the orbiting satellite with the mission of missile launching.

While substantial arguments can be adduced in favour of establishing missile-launching bases on the moon, equally sound criticisms of the lunar-base proposal cast grave doubts on the feasibility and effectiveness of such a project. Many of the critical weaknesses in the exaggerated claims that the space satellite can bring about world dominance and consequent world peace are equally true of the lunar-base proposal. Since a number of rocket engineers have in the past chosen to publicize the merits of the lunar rocket base, and since there is a marked distinction between the satellite bombing-platform and the moon rocket base, a critical evaluation of the latter may be of interest.

The basic arguments justifying the creation of the moon rocket base are that it can enjoy the advantages of dispersion and camouflage; that it is a fixed base of operations; that it is well suited to defence; and that the base will be completely capable of self-support by the time we are ready to establish permanent facilities on the moon.

The missile required for terrestrial bombardment is not an outsize or unduly expensive affair. Even the V-2, capable of a velocity of only 3,600 miles per hour on the earth, can be launched from the moon. On the earth its performance is limited by a motor which must operate below its maximum efficiency because of the surrounding atmosphere; furthermore, in its upward climb it must battle earth's gravity and overcome the physical resistance of the atmosphere. On the moon the motor would operate with maximum thrust, there would be no resisting air medium, and the rocket need overcome only one-sixth as much gravity. If these favourable conditions were insufficient to permit complete escape from the moon's gravitational field, a rocket booster would bridge the gap. Rocket development has already produced a motor one-third the size of the V-2's power unit which burns only one-third as much fuel, and delivers an equal amount of thrust. The lunar missile, therefore, presents no problem which is not now capable of solution.

Any proposal for the creation of rocket-launching facilities on the moon must assume that the extensive programme of constructing space ships and satellites and dispatching expeditions to the moon will be entirely successful. It must also assume success in effective air and water recovery and possibly in the extraction of these vital necessities directly from the materials indigenous to the moon.

Detailed investigation of the problems of the lunar base leads to the conclusion that the military superiority claimed for the moon-launched rockets is insufficient to overcome the overwhelming difficulties and negligible value of such a project. Unless fuels of the specific types required for propelling the missiles can be manufactured locally, it would be necessary to transport and store on the moon thousands of tons of such chemicals. An even more difficult problem than that of transporting fuel from the earth is that of

storing it over long periods of time; the instability of rocket fuels would make this an almost insuperable undertaking.

The hundreds of guided missiles required for any substantial bombardment of terrestrial targets would require transportation from the earth to the moon at great expense in cargo rocket fuel. It would be necessary to carve heated, illuminated, and pressurized subterranean caverns from the lunar mountains to store the rockets and allow maintenance crews to service the intricate missile mechanisms. Although the contemplation of permanent lunar installations for scientific and limited industrial purposes is kept within the bounds of reality, the idea of creating an industry on the moon merely to manufacture the components of guided missiles for attack on the earth is an abuse of realistic imagination. Only through such an industry on the moon could there be any hope of overcoming the tremendous problem of transporting hundreds of guided missiles to the moon.

A very large portion of the productive facilities of any permanent lunar installation would necessarily be devoted to the support of military facilities, if the rocket launching-sites were actually developed. The eventual value to be gained from these lunar installations through a maximum of scientific, technological, and industrial effort would be obviated by the senseless drain of military needs.

A further examination of the role of the lunar base in any attack upon the earth leads to identical criticisms of the space bombing-platform. It will require the passage of many years before a permanent scientific group can be left on the moon, and additional years thereafter to develop technological processes to allow realization of the diverse activities elaborated upon in the previous chapter. By that time, of course, missile guidance may have advanced so greatly that effective control of the moon-to-earth rocket will be possible.

Fundamentally, the same criticism made of the space bombing-platform applies here: Why transport rockets, fuel, war-heads, instruments, and accessories across a quarter-million miles of space and support the launching-sites with a small army of technicians, only to throw these missiles back to earth, when rockets launched from the earth are just as effective, and probably more so?

Camouflage and dispersion tactics are familiar procedures on the earth, where they can be accomplished with infinitely greater ease than on the moon. Transportation, communication, personnel maintenance, and other requirements of any hidden rocket launching-site on the earth are matters of routine. The control mechanisms required for surface-to-surface bombardment are even now evolving into reliable guidance systems; although they are not yet good enough to assure the desired accuracy, they nevertheless promise effective control of atomic war-heads aimed at enemy targets. Engineers predict that, within a decade, such missiles will be sufficiently accurate to render obsolete the familiar intercontinental heavy bomber. The rocket launching-base on the moon, therefore, accomplishes nothing beyond that which is possible with rocket installations on the earth.

One purpose of this book is to present as many of the creditable proposals for the conquest of space as possible, and to enlarge upon the consequences and benefits of man's greatest adventure. Rocket launching-bases on the moon have too long been publicized as a natural outgrowth of space travel, but no realistic studies have been made of the assumptions on which they rest. For past years, when the dream of space travel seemed much less realizable than it does today, almost any proposal could be advanced without fear that it would be subjected to careful scrutiny. However, as space travel emerges from the realm of fiction and evolves into a scientific

concept, it must submit to the examination of practical engineers. As it slowly approaches the possibility of realization and implementation, it becomes increasingly essential that vital and provable facts sustain the arguments made for its feasibility. A continued approach to its numerous problems through fantasy rather than sober scientific reasoning and deduction can serve only to keep the project in the realm of the dream and the imagination, with the unhappy result that it will never achieve the recognition and acceptance in the public mind which its surprisingly rapid development merits. A rocket launching-base on the moon, however stimulating to the mind spoon-fed on the more fantastic science-fiction, can never be more than a minor secondary element in a general programme which envisions great scientific advances. Constant reiteration of the destructive possibilities of space travel and repeated emphasis on such unscientific proposals as the establishment of military bases on the moon, especially when they are founded on the fallacious premises we have examined and exposed, can serve only to bring a sober scientific concept, which should be clothed with dignity, into disrepute.

10

Beyond the moon

It is difficult if not altogether impossible to predict the exact time when man will eventually set foot on planets other than his own. Before any attempt to bridge the void separating earth fom its celestial neighbours is undertaken, the multifarious problems involved in establishing space satellites and exploring the moon must be successfully met. Interplanetary travel must be preceded not only by space stations and lunar exploration but also by significant advances in power, fuels, and performance. Our existing technology promises to develop a vehicle capable of travel to satellite orbits and the moon, while remaining within the limitations of military, economic, and scientific demands. The interplanetary vehicle, because of the uncompleted research required to effect even a limited conquest of space, deserves little more than speculation.

There is little need for serious engineering concern about space ships which, in any event, can be no more than the natural successors to the yet non-existent vessels designed for limited journeys beyond the earth. Rocket engineers and scientists, however, have frequently forecast the dimensions, performance, construction, and design of the interplanetary space ship. One of the more outstanding proposals, that advanced by Arthur C. Clarke, ex-Chairman of the British Interplanetary Society, visualizes a nuclear-powered vehicle with the

configuration of an immense dumb-bell. The smaller sphere of the dumb-bell space ship contains the heavily shielded nuclear reactor and the propulsion unit. An extended circular "tube" runs from the reactor section to the larger spherical personnel and cargo section, comprising the forward part of the unusual space-ship design.

Clarke's space ship will never descend to any planet's surface; it is designed only for travel between planets. The atomic drive of the dumb-bell space ship will produce a very gradual acceleration, never exceeding a rate of more than 1 g.

The nuclear vehicle will be assembled in space above the earth and, when completed, will already be moving at a velocity of more than 16,000 miles per hour. To leave the satellite orbit will not require great initial acceleration, but it can gradually build up sufficient momentum to escape from the gravitational pull of the earth. The atomic reactor does not generate hundreds of tons of thrust, as do the earth-to-orbit chemical rockets. For ever hanging in space, however, the space ship is weightless. The gases expelled from the reactor are great enough gradually to overcome the inertia of the vehicle and build up very high velocities.

The great distances required to build up sufficient velocity for interplanetary voyages are insignificant, since the atomic space ship has virtually limitless area in which to operate, and has an "inexhaustible" fuel supply. In a journey from the earth to Mars, for example, the space ship would build up additional velocity which, added to the orbiting movement, would be sufficient to enable it to break free of the earth's gravity and continue into space. When the vehicle finally reached Mars it would manœuvre into a free-fall orbit about the planet, remaining above Mars as long as was desired without any additional power manœuvres.

Smaller chemically-powered rocket craft would be employed to land on the red planet. As an expeditionary vessel, the atomic space ship could accommodate landing space ships, and the necessary fuel and equipment to operate these smaller vehicles. While the larger space ship orbited about the planet, the landing ships would be assembled in space and launched to the world below. Study and exploration of the planetoids and larger asteroids would not require exploration space ships; due to the negligible gravitational attraction, special space taxis would suffice.

For an expedition to Mars, Wernher von Braun recommends the employment of 70 men, travelling in ten space ships which also carry three winged "landing-boats" for surface exploration. Previous suggestions made by von Braun for extraterrestrial activities are dwarfed by the immensity of the Mars project. He proposes that, after completion of the space satellite, preparations be made for a scientific investigation of Mars. Each of the ten space ships envisioned for this vast undertaking are to be 134 feet in length, 95 feet in diameter, and each accommodate 3,660 tons of chemical propellants. Of the ten orbit-to-orbit space ships, only seven will make the return trip; the other three are to be abandoned in the Martian orbit.

Forty-six three-stage cargo rockets are to be employed for the construction of the ten interplanetary vessels, in a round-the-clock construction operation. Nine hundred and fifty flights by the 46 space ships will be necessary to transfer cargo, equipment, men, and fuel from the earth into the satellite orbit. If 6,000 tons of propellants are consumed by each space ship, the 950 shuttle flights will require a total consumption of nearly six million tons of hydrazine and nitric acid—just to carry materials into space! This figure does not include a minimum expected attrition of space ships and

their components through operational mishaps. To establish a basis for understanding the fantastic weight of the fuel necessary to accomplish this construction project, we should remember that during World War II all the aeroplanes in the United States Army Air Forces together dropped on enemy targets just over two million tons of bombs. The von Braun Mars expedition project would require the burning of nearly three times as great a quantity of fuel alone.

Since the space ships will never descend to the surface of Mars, both streamlining and landing gear are unnecessary. Inasmuch as the voyage is started from an orbit about the earth, the thrust rating of the power plants, unlike that of an earth-to-space rocket, need be only a fraction of the vehicle's initial weight. Although each ship carries nearly 3,700 tons of fuel, the thrust generated by the rocket motors is only 200 tons.

Three of the orbit-to-orbit space ships carry a landing-boat sufficiently large to transfer 50 of the 70-man scientific complement to the surface of Mars. Each boat weight 200 tons fully loaded. Since one boat will be abandoned on the planet, its payload from the Mars orbit to the surface will be at least 100 tons. The 50 men are divided among the three boats during the descent and are returned to the orbit in two boats. Since Mars has a surface atmosphere corresponding to that of the earth at a height of approximately 50,000 feet, each landing-boat can descend in the manner of a high-speed aeroplane. Although the rarefied atmosphere reduces the effective lift of any winged craft, the lower gravity of Mars' surface, only two-fifths that of the earth, correspondingly reduces the "weight" of the landing-boat supported by those wings. Von Braun estimates that for such a landing speed as would be desired on earth, the wing area

of the Martian boats must be four times as great. The three ships will touch down at about 120 miles per hour.

The entire expeditionary trip will require two years, 239 days; or a total of 969 days. Of this time, 260 will be consumed for each trip between earth and Mars. The ten space ships will orbit about the small planet for a total of 449 days, during which the 50 men will remain on the surface for 400 days.

The preceding figures immediately indicate the immensity of the entire scheme. While the project may indicate technical success, it hardly seems practicable. There appears to be no escape from the incredible costs which, on the basis of financial estimates for the satellite, would run into many billions of dollars. Whatever scientific or allied justification may be adduced for an expedition to Mars, it is difficult to accept the need for 70 men, with required support in such items, as air, food, water, and other equipment, when a much fewer number could carry out the projected scientific purposes.

A word of caution must precede the following description of the planets of the solar system. Even so-called accepted facts about the other worlds circling the sun are subject to possibly drastic revision. Many hundreds of millions of miles separate the earth from the other planets; there are many obstacles to astronomical observations through the atmosphere; reflected sunlight limits spectroscopic studies of the planets; and the atmosphere surrounding many planets is impenetrable. These are only a few of the hurdles to be mastered in accurately determining conditions on other worlds. The descriptions of these worlds, therefore, are based upon the most exact data accumulated by astronomical science on this subject; unfortunately even the experts are at times in violent disagreement with one another on specific matters. Until space ships actually transport

men through the void, we must have reservations about so-called definite facts about these strange and fascinating planets.

Through the Solar System

One half seared by blasting radiation from the stellar inferno raging less than 30 million miles distant, the other half frozen and shrouded in perpetual darkness, the innermost world of our stellar system races through space at a speed of more than 30 miles a second. Three thousand miles in diameter and smaller than several of the moons in the solar system, Mercury is a forbidding, lifeless world of paradoxical extreme heat and cold.

Any space ships which land on this airless globe must, if descending upon the heat-washed surface exposed to pitiless solar radiation, be protected against a constant surface temperature known to exceed 700° Fahrenheit. Under such temperature conditions, tin and lead lose all resemblance to the metals we recognize and revert to a state of bubbling liquidity. Because of the violent heat and possibly semi-molten surface conditions, it would probably be necessary to effect a landing in the area popularly termed the "twilight zone." Mercury wobbles erratically on its axis as it whirls about the sun and completes a revolution once every 88 days. This inconsistent axial motion creates a narrow strip across the planet between the areas of permanent heat and unchanging cold. A space ship descending among the jagged mountains and crags would land in an indeterminate belt of temperature which rises and falls as the planet's unstable motion exposes or hides the landing-area from the sun.

Surface exploration, if such activity were to be carried out on this hostile planet, would be conducted best from this area. A landing

on the planet surface facing away from the sun might resemble a descent upon the surface of the night-shrouded moon. Mercury is not much larger than the moon and possesses a surface gravity only slightly greater. It is difficult to see what purpose would be served by an extended visit to Mercury. Extremely hot, bitterly cold, barren, lifeless, and precarious to human visitors, it is a world which may well escape the close attention of mankind.

For many years the planet Venus has been a favourite subject for science-fiction writers, who have pictured the world second in space from the sun as a cloud- and steam-enshrouded watery globe of dense and lush jungles, in a state of development corresponding to earth's early Paleozoic era. Such journalistic nonsense depicts terrifying monsters and weird Venusian swamp men at varying stages of technological development; they are either simple natives or jungle-world geniuses. A more realistic view paints another picture. The most exhaustive scientific study of this brightly shining planet leads inevitably to the conclusion that Venus is an arid, harsh, wind- and sand-swept, lifeless globe. All our studies of its atmosphere have failed to detect any traces of water vapour or oxygen; this would eliminate any possibility that the planet teems with plant and water life.

Venus has long been termed earth's sister-planet, primarily because of a physical size, which is almost identical to that of our world. Venus' diameter of 7,700 miles brings it almost within the physical dimensions of the earth. The planet's mass gives it a surface gravity nine-tenths that of the earth. With the exception of the moon, Venus approaches us more closely than any other major body in the solar system; it is only 25 million miles away when at the closest, and 161 million miles at the point of greatest separation. One

Venusian year is completed in 225 earth days, since the planet, closer to the earth than it is to the sun, moves through the system at nearly 22 miles per second.

One can hardly blame the more lurid writers for indiscreetly describing Venus as a watery globe. Surrounded by a virtually impenetrable cloud cover which from the earth appears to make Venus shine with ten times the brilliance of the brightest star, Sirius, the planet's surface has never been directly studied by man. The thick cloud covers of Venus led to the apparently logical conclusion that the clouds greatly resembled terrestrial rain clouds. There was every reason to follow this line of thought; the planet was of the same dimensions as the earth, and its proximity to the sun implied the existence of a high surface temperature. Obviously, then, Venus was in a process of surface development corresponding to that which occurred in the earth's early days. This concept was destroyed when astronomical studies not only failed to detect water vapour and oxygen but indicated the existence of vast quantities of carbon dioxide, sand, and dust. These studies indicated a carbon-dioxide concentration more than 100 times that of the earth's atmosphere. Venus is not only bone-dry, but its atmosphere is lethal to man.

From what we can determine of the thick carbon-dioxide-and-sand atmosphere of Venus, it is probable that a space-ship landing would be a "blind" one, with radarscopes selecting an area free of mountains and crags. If any landing is ever made on Venus, the great risk of descending through the turbulent atmosphere would require the development of superior space-ship propulsion methods which are many years in the future. The space ship would necessarily be capable of maximum motor operation for a period much more extensive than that required merely for descent and take-off;

the probable need for emergency power on Venus demands a high reserve.

The blinding atmosphere would not be the only untoward factor; the powerful winds might well wreck any surface exploratory venture. Scientists are not certain that Venus rotates on its axis; if such rotation occurs, it is extremely slow. Together with the thick, covering atmosphere, this condition creates what is known as the "greenhouse effect." At a distance of only 67 million miles, the sun's great heat produces surface temperatures of more than 200° Fahrenheit on the side which it strikes directly. Turned away from the sun's rays for many weeks or months at a time, the dark hemisphere is extremely cold. The unusual atmosphere with its high percentage of carbon dioxide allows the short heat-producing rays of sunlight to pass through to the ground; the long rays are imprisoned. Temperature in the sunlit area soars, but plummets in the darkened area. This great variation creates violent windstorms which hurl about hundreds of millions of tons of sand and dust.

Spacesuited explorers on Venus would be unable to venture far from their space ship; in the interests of survival they would be secured to the vessel by long lines. Barely glimpsed through the swirling sand, the sun would be a great glowing copper disc. These howling wind- and sand-storms make relatively insignificant even the worst of the dreaded storms of the Sahara Desert. Dry, reddish soil of a sandlike consistency is constantly hurled and whipped through the air by the fierce winds. Great dunes "march" across the surface before the howling tempests, ever changing their shape and position. Mountains and rocks are polished to a glassy smoothness by the grinding, wearing effect of sand particles moving at great speeds. Notwithstanding its closeness to the sun, Venus is a world existing in almost perpetual

gloom. The dust-laden atmosphere obscures the sun, and at times brings rapid night even to the "sunlit" areas of the surface. This violence of sand and wind may prevent any space ship from landing on this savage world.

There is no possibility that life can exist in this unceasing maelstrom of wind, sand, and extremes of temperature. There can be little justification for assuming the extreme risks involved in attempting a surface landing. In all probability, study of this forsaken world must be left to the probing ability of instruments mounted within space ships orbiting about the planet.

A Hope for Life

Of the eight other planets in the solar system scientists look to Mars as the only world capable of supporting life. The most startling single fact about the red planet is that in centuries past intelligent life may have existed and just possibly have managed to survive to this day.

Mars is frequently described as an old and dying world, with its atmosphere disappearing into space and its life succumbing to the inexorable advance of cold and to the loss of its slight remaining surface moisture. Actually, Mars is no older than the earth, in the sense of having existed before the earth's creation. A smaller world than our own, with only 38 per cent of the earth's surface gravity, Mars began to lose its heat, water vapour, and atmosphere into space eons past. Much farther from the sun than earth, it is 128,330,000 miles distant at the closest approach and 154,760,000 miles away at the extreme limit of its orbit. Because of this distance, Mars has always received less heat than the earth and consequently cooled off

more rapidly. Mars, therefore, is a victim of planetary "old age," while the earth remains fertile and rich.

There is good reason to assume the existence of some life forms on the red planet, although astronomers disagree as to the type of life which may exist on the little world. The first scientifically reliable estimate of life on Mars was made against the background of a flurry of international excitement in September of 1877, when the Italian astronomer Giovanni Schiaparelli announced that he had sighted surface features which were "drawn with absolute geometrical precision, as if the work of rule or compass." Schiaparelli had studied Mars for years and like other astronomers had observed the bright orange patches believed to be dry land, the bluish-green dark patches, and the brilliantly white polar caps which grew and receded with the Martian seasons.

In 1877 Mars was only 35 million miles from the earth, permitting unprecedented telescopic examination. Schiaparelli discovered dusky streaks connecting the orange and blue-green areas of Mars which were, he wrote, absolutely symmetrical. Not only were the geometric lines unexplained by any natural causes, but during the months following the melting of the polar cap they were doubled. Within a few days after the cap had begun to melt, the original single hazy line was transformed into two distinct parallel lines. Schiaparelli called these lines *canali*, which may be literally translated as "channels."

The word was mistakenly translated as "canals" by many astronomers in the United States; thus, Schiaparelli's findings initiated studies of Mars which eventuated in claims that the "canals" were constructed by intelligent beings to facilitate the distribution of water across the barren surface during the melting of the polar cap.

By 1894 Percival Lowell was conducting a close study of Mars from his observatory at Flagstaff, Arizona. Lowell had no doubts, in a field where Schiaparelli properly hesitated to be categorical, as to the purpose of the *canali.* Lowell was convinced that Mars was inhabited by intelligent beings, and supported his claims with a map of the planet showing an intricate geometric network of nearly 700 single and double canals. Lowell claimed that the light areas of Mars were really scorched and barren deserts, and that water existed only in the region of the polar caps; to prolong the life of the planet and provide irrigation for plants, the Martians supposedly had constructed the vast network of canals to distribute the water of the melting icecaps during the Martian summer. Lowell contended that the parallel lines seen by himself, Schiaparelli, and other astronomers were not actually the canals, too small to be seen by telescope, but were the irrigated bands of vegetation bordering the artificial waterways. During the melting of the icecaps the presence of vegetation indicated the course of the water as it flowed towards the Martian equator.

Lowell's theories have been supported and derided with equal vehemence. It is interesting to note that the latest observations made with greatly improved astronomical instruments support many of Lowell's claims, and that they have failed to disprove many of the more controversial contentions. There is yet no agreement as to whether or not intelligent life once inhabited the red planet and whether it may continue to exist. On one controversial point, however, modern astronomers agree with Schiaparelli and Lowell: The unexplained parallel lines on the surface of Mars do exist. That admission is the strongest argument for past or present intelligent life on Mars, for their geometric character can only be artificial in origin. Opposing astronomers scoff at such beliefs, insisting that if such lines exist

they can be only great fissures and cracks in the surfaces of a nearly barren world. The realistic dissenters point out that telescopic observation of Mars under even the best possible atmospheric conditions is attended by great difficulty; it resembles examination of a child's dull-red marble with the naked eye at a distance of perhaps three feet.

Modern instruments enable astronomers to see conditions on Mars which remained hidden to Lowell. The modern telescopic camera responding to haze-cutting infra-red and short-wave ultraviolet light rays can reveal conditions invisible to the eye. High-speed motion picture photography, taking thousands of feet of film of the planet through the most powerful telescopes, may turn up several frames exposed at the exact moment when the exceedingly rare perfect-seeing conditions appear. The spectroscope, thermocouples, and other astronomical devices permit detailed analysis of Martian surface conditions that paint a surprisingly realistic picture of the planet.

The two Martian moons, Deimos and Phobos, represent one of the outstanding wonders of the solar system. The inner moon Phobos whirls about Mars so rapidly that it actually appears to rise in the west and settle in the east, and requires only slightly more than four hours for the entire horizon-to-horizon movement. Deimos exhibits the characteristics of our own moon, despite its own peculiarities that include a rapid eastward movement which exceeds the speed of the planet's rotation. During its transit across the Martian heavens, it appears to hang motionless in the sky; it is not until 60 hours after rising that Deimos disappears over the horizon. During this interval the smaller Phobos has completed two complete orbits of the planet. Phobos and Deimos, respectively five and ten miles in diameter, can hardly be characterized by the word "moon" as we know

it, for they are smaller than hundreds of asteroids wandering through the solar system.

Generally speaking, to support life a planet must have a reasonable surface temperature somewhere below the normal boiling point of water and rising above the freezing point at least part of the time. In addition, some water and oxygen must be available in the atmosphere. Since there is evidence of some water on Mars, the existence of plant life appears not only possible but extremely probable. In the dark greenish areas which change in unison with the Martian seasons, astronomers believe they are witnessing the annual growth and disappearance of vegetation. Spectographic study of the surface reveals that the light reflected from the dark areas of Mars resembles in many respects the light reflected from terrestrial lichens and mosses. The ability of such plants on the earth to exist in high, mountainous, cold, and wind-swept areas leads to the logical conclusion that similar plant life could well survive even the austerity of the Martian surface.

Five-eighths of Mars is an arid world, bare, sterile, oxygen-starved, cold, and exposed to the pitiless glare of an unshielded sun. There are no mountains, and even the largest hills probably do not rise to more than 2,000 to 3,000 feet above the surface. Deadly monotony is the dominant surface characteristic. Bleak and bare, much of the planet is covered with yellow and reddish-brown sand and finely powdered soil which drift idly with the breeze or are driven by the fierce winds that sweep across the hills. Astronomers believe that the devastating sandstorms of Mars stretch like giant walls of dust moving across the vast expanse of desert. Small rock outcroppings are blasted by the hurtling grains of sand and dust, which pile up into crescent dunes or stretch across the surface in rippled waves. Bluish-white clouds, probably composed of minute

frozen ice particles, drift from six to 19 miles above the surface. Below these cirrus-like clouds is a thin stratum of violet haze, which is believed to be made up of widely dispersed ice crystals. Sweeping up to three miles above the sandy desert, yellow clouds of sand and dust roll before the wind.

There is no doubt of the existence of an atmosphere; however, the gaseous components of heat atmosphere have not been identified. Carbon dioxide has been definitely ascertained as a major constituent of the surface gases; nitrogen is believed to make up a large portion of the air; and oxygen may be present in very low percentages. The existence of water vapour in some amounts is strongly implied by the presence of the clouds and by the seasonal melting of the polar caps. These caps, incidentally, are not to be misunderstood as resembling those of our polar regions, which are in many places thousands of feet thick. On Mars this ice is probably no more than several inches thick, which accounts for its rapid disappearance during the summer months.

The dark areas which appear following the melting of the icecaps move towards the equator at the rate of nearly 30 miles a day. Scientists still disagree as to the disposition of the water from the melted icecaps. One school believes it is absorbed by the spongy soil beneath the ice; another holds that the moisture is picked up by the wind and clouds and deposited southward in the form of heavy mist or dew.

It is believed that if animal life has managed to survive under the bleak conditions prevalent on the Martian surface it must in all probability be of the lowest order. Those who believe in the existence of such animal life point out that several species of animals on the earth exist without ever drinking water, and that following a much stricter demand for survival on Mars such life must have adapted

itself to prevailing conditions many thousands of years ago. There is good reason to believe that the lowest forms of life, such as worms and insects, still survive below the surface, for even on oxygen-rich earth some forms of worms can exist without atmospheric oxygen.

Most scientists believe that Mars was once as rich in oxygen as is the earth today. Millions of years after its atmosphere lost this vital life-sustaining gas into space, considerable oxygen may still be present as a mixture with the iron in the soil. This chemical combination would serve to explain the distinctive red colour which may be attributed to a surface deposit of iron rust.

A space ship could land on Mars if it were equipped with wings of considerable area. Human explorers would require the protection of a complete spacesuit equipment, since the surface atmospheric pressure is equal only to that existing at a height of about 50,000 feet above the earth. Even if there were a high percentage of oxygen on Mars, the low density would require that oxygen be forced into the body under pressure. Lacking the protection of a spacesuit, a man would literally have his body moisture sucked away by the dryness of the air, splitting the skin and nails. Temperatures on Mars are on the average 60 degrees lower than the equivalent average of the earth, ranging from a comfortable 70° Fahrenheit at the noonday equator to more than 100° below zero during the night.

The greyish-green mosslike plants, sometimes showing hints of yellow, brown, and black, are flat, crustal, surface growths which spring into life with the melting of the polar caps. Lichen growths appear sporadically beyond the areas "rich" in moisture and are fed by the moisture blown from the melting polar caps by high winds. In the desert regions much of the surface is covered with volcanic pumice resembling that which covers the surface of the

moon. Silica, a basic component of sand, is also present in large quantities.

We cannot now reach any definite conclusion as to whether or not intelligent life once existed on Mars; even less can we determine whether it manages to survive the bleak conditions existing on the red planet. What we do know is that the surface lines on Mars cannot be explained by any natural causes, and that the evidence strongly favours a belief in the existence of past civilization.

Inhospitable Jupiter

The giant of the solar system, the planetary colossus Jupiter, will never be visited directly by earthmen. The incredible surface conditions of a poisonous atmosphere denser than metal, a surface gravity several times that of the earth, and winds of many hundreds of miles per hour make it obvious that Jupiter is a world destined to be studied from a safe distance. This is a planet with a volume more than 1,000 times that of earth, and with a mass equal to 300 times that of our globe.

Of all the worlds in the system, Jupiter is truly the most fantastic. With a diameter of 88,700 miles, it is the fastest-rotating planet, completing a full rotation once every ten hours. This equals a rotational movement at the equatorial surface of about 25,000 miles per hour. This great axial speed, together with the pressure of a dense atmosphere which extends for many hundreds of miles above the surface into space, creates a "flattening out" of the planet at the poles.

Seen through a telescope, Jupiter is streaked white, pink, yellow, and green, divided by darker brown and red "belts." There are irregular areas of bright green and blue and brilliantly white oval

patches. For many years astronomers tended to regard the colours exhibited by the massive planet as purely optical illusions, but recent photometric investigation and monochromatic photographs have confirmed the reality of these colorations. The surface conditions never remain permanent but are subject to continuous and rapid changes which often occur directly before the telescopic viewer's eyes; these bear witness to the atmospheric cataclysms compared with which our most violent storms are mere breezes. The winds roar above the planet at speeds greater than 300 miles per hour.

No space ship will ever descend into the Jovian atmosphere. The goliath of the solar system exhibits temperature readings at the outer atmosphere surface of $-150°$ Centigrade, but this bitterly cold condition fails to prevail near the surface. Scientists have determined from the incredible movement and density of the atmosphere that the surface temperature is many hundreds of degrees above zero. It is believed that the interior composition of Jupiter and similar great bodies is actually semi-stellar in nature, and that the tremendous heat transmitted from the planet's interior also serves to raise surface temperatures to high levels.

As Jupiter cooled in the course of its evolution, the abundant hydrogen and other major gases in the atmosphere combined to form compounds of methane, water, and ammonia. The basic atmosphere now consists of ammonia in the form of minute ice crystals mixed with the methane. The water in Jupiter's atmosphere has long since frozen and descended as a rock-hard mass. Metallic sodium combining with the high quantities of ammonia account in great part for the bright and rapidly changing colours of Jupiter's upper atmosphere.

The semi-stellar interior, great surface gravity, constant volcanic

eruptions on a mammoth scale, incredible winds, and atmospheric density make Jupiter a world of unceasing violence on a scale unmatched anywhere in the solar system. About 40 miles below the level where the pressure of the atmosphere is equal to that existing at the surface of the earth, the air becomes as dense as platinum, yet continues to move with great velocity. Even the lighter gases of helium and hydrogen are compressed into strange substances with metallic density. Nearly perpetual darkness reigns on the surface. Flaming hydrogen gas, liquid lava, and steam erupt constantly from the molten bowels of the planet to shear gaps in the surface, and continue many miles upward into the strange metallic atmosphere. The repeated explosions from the volcanic upheavals churn seas of liquid ammonia into thundering successions of tidal waves which pound against steaming mountains that rise from the surface and often disappear in the hideous surface upheavals. Jupiter is a world of death and violence, utterly hostile to any form of life.

This planet has often been described as a miniature solar system, with 12 moons which whirl in their orbits about the mother world. The largest of these dozen satellites is Europa, about 416,000 miles from the planet, or a little less than twice the distance of the moon from the earth. Its diameter not only is greater than that of the moon but exceeds that of Mercury. The 3,000-mile-diameter Europa is also singular in the fact that it possesses an atmosphere and a frozen surface of nightmarish gases and ice. Ganymede is another giant satellite at least the size of Mercury and with a mass twice that of the earth's moon. At least four of Jupiter's moons exceed the earth's satellite in size, with diameters greater than 2,300 miles. These circle about the mother planet in orbits requiring from two to 17 days for a complete revolution. The innermost satellite, 112,600 miles from Jupiter and only 160 miles in diameter, is a mass of irregularly

shaped rock moving in its orbit at a speed of more than 60,000 miles per hour.

Nearly 12 earth years are required for the planet to complete a revolution about the sun. Whirling in its orbit as close as 459 million miles to the sun, Jupiter's elliptical swing also sends it more than 506,700,000 miles into space from its parent star. Man will never visit this world directly but will conduct his scientific examination of the planet from one or several of the dozen moons.

Moving slowly about a sun which at its nearest is 863,700,000 miles away and 935,570,000 miles distant at the point of greatest separation, the great planet Saturn requires nearly 30 years to complete a revolution about the sun. Although nearly as large as Jupiter, with a diameter of more than 75,000 miles, and possessing nine satellites, Saturn is famous chiefly for its beautiful formation of rings circling the planet.

These three great rings have an extreme diameter of 172,000 miles, but a maximum thickness of only ten to 20 miles. This incredible ratio of one to more than 17,000 produces the thinnest and flattest natural surface known in all space. A model of the Saturnian rings would be a sheet of metal in the form of a perfect circle at least five feet in diameter and no thicker than this page. Of the three rings, the innermost is the brightest and revolves about the planet more rapidly than do the two outer formations. Separated by a space of 4,000 miles, the outer rings are so close together that they appear to merge as a single great circle. Photographs of Saturn often show a wide shadow cast on the planet's surface by the rings which, although extremely thin, are sufficiently wide to throw a very broad band of shade across the planet. These rings were once thought to be composed of rocks from a moon which approached Saturn too closely and was shattered by opposing gravitational forces; modern

astronomy, however, has revealed that they are actually a vast accumulation of ice chunks with an outer layer of hoar frost, a silvery-white deposit of ice crystals.

Although almost as large as Jupiter, Saturn has a surface gravity only slightly greater than that of the earth. The hard, dense core of the planet comprises only 10 per cent of the planet's entire mass; the remainder is made up of gases solidified under great pressure. Generally similar to that of Jupiter, Saturn's atmosphere appears to have a higher concentration of methane and less ammonia. Surface bands of white, orange, yellow, green, and red are clearly evident; these slowly change their shape and colour gradations. Large-scale disturbances are occasionally witnessed on the surface, but on a scale far below that seen on turbulent Jupiter. The surface temperature of the more distant Saturn is approximately 300° below zero Fahrenheit.

Of the nine satellites orbiting about Saturn, Titan with a diameter of 3,350 miles is the largest of the many planetary satellites in the solar system. It is also the only moon with an extensive atmosphere consisting mainly of methane and lesser quantities of ammonia. Japetus, 2,210,000 miles from Saturn and half the size of earth's moon, has long baffled astronomers with its astounding surface conditions. One half of Japetus is five times brighter than the other.

The other Planets

Beyond the orbit of Saturn swing the three remaining worlds of the solar system. These planets, although differing in various respects, resemble each other in the fact that their surface gaseous atmospheres are frozen solid by the appalling cold, and in the further fact that

they are utterly lifeless. To complete one revolution about the sun Uranus and its five moons require the passing of 84 earth years. Although nearly 31,000 miles in diameter, the planet's bulk consists mainly of frozen surface gases; these create a surface gravity approximately equal to that of earth. Surface temperature is almost a constant 380° below zero Fahrenheit.

With a diameter of 33,000 miles, approximately the same as that of Uranus, Neptune and its two moons revolve about the sun once every 164 years. It is more than 2,817 million miles from the sun, which appears in the black sky as a gleaming light only slightly brighter than the major stars. Uranus and Neptune greatly resemble each other, and their comparative brightness as seen in telescopes is accounted for by their frozen atmospheres of ice and snow which form excellent reflectors of light from the distant sun.

At the known edge of the solar system lies the forbidding world of Pluto, having almost the same diameter as the earth but bearing no resemblance to this warm, green planet. The temperature on this world is nearly absolute zero, −459° Fahrenheit. Everything is frozen solid; there is no sound and no movement, and only the barest light from the sun, hardly distinguishable from other stars, an incredible 4,300 million miles away. Nearly 248 years pass before Pluto completes a single circuit about the sun. It is of little matter. Pluto is the lifeless end of the solar system.

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